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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01R

A2

(11) International Publication Number: WO 99/02996

(43) International Publication Date: 21 January 1999 (21.01.99)

(21) International Application Number: PCT/US98/12239

(22) International Filing Date: 18 June 1998 (18.06.98)

(30) Priority Data: 08/890,816 11 July 1997 (11.07.97) US

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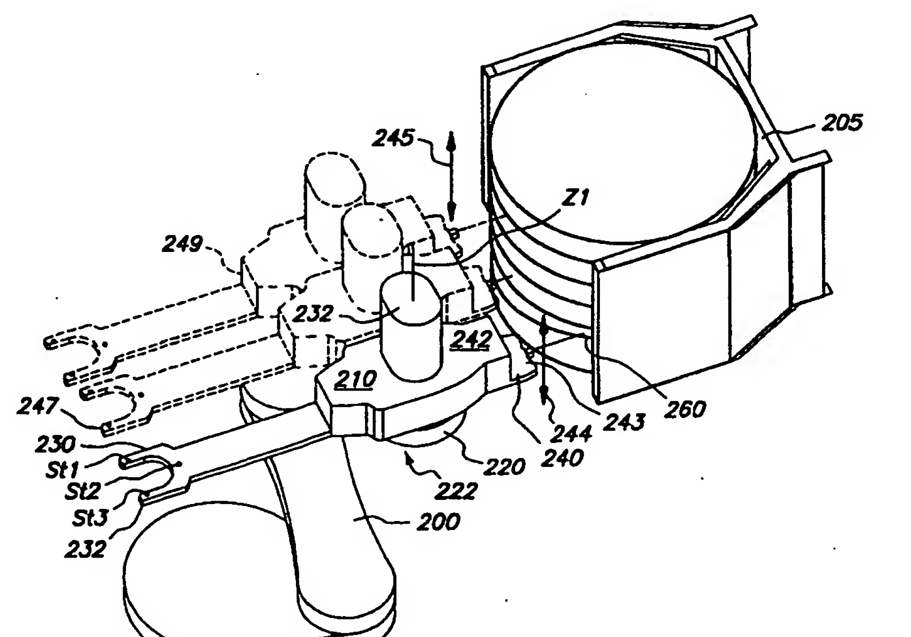
(81) Designated States: IL, JP, KR, SG, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: MULTIPLE POINT POSITION SCANNING SYSTEM

(57) Abstract

A multiple point scanning system is suitable for determining the orientation in space of a substrate such as a flat panel display or semiconductor wafer. The substrate or semiconductor display may be positioned in the wafer carrier, and the system of the present invention can determine the position of the carrier, in order to calibrate and teach a positioning robot or other mechanism the position of the carrier. Using top scanning sensors, X-Y coordinates of the wafer or substrate can be determined, and the actual position of the wafer calculated. The system includes a scanning end effector (100,102) which may be utilized with an end effector structure, the end effector structure having a first end and a second end, the first end including a forward scanning sensor (FS) and the second end including top scanning sensors (TS). The scanning end effector may be rotated about a Z-axis extending through a robotic arm, such as a global positioning arm to position the scanning end effector relative to both the wafer holder and the substrates. The system may also include a rear scanning sensor (424) coupled to a sensor frame (450). The sensor frame may be positioned along the Z-axis when an end effector engages the scanning frame and moves the frame along the Z-axis in conjunction with the scanning motion of the end effector. In yet another alternative embodiment of the present invention, three sensors are located in a chamber or front-end set-up at three different locations in an X-Y plane, to sense the Z-axis coordinates of a substrate or wafer in a front-end processor which is positionable on an elevator or global alignment elevator. The system may be used in conjunction with a robotic arm or global positioning robot having one or more vertical detection sensors.



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MULTIPLE POINT POSITION SCANNING SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates to the detection and handling of substrates in a carrier, such as, for example, to semiconductor wafer substrates in a wafer carrier, or to substrates such as flat panel displays in front-end processing equipment.

Description of the Related Art

Automated robotic positioning systems are utilized to manipulate a number of types of substrates, such as semiconductor wafers and flat panel displays, through a sequence of manufacturing process steps. Semiconductor wafers, for example, are provided in a wafer carrier such as a SMIF pod or other housing, and positioned by a robot or robotic arm structure (which may include a Z-axis positioning elevator) through individual wafer processing steps, between different apparatuses or within a single apparatus. Flat panel displays are, for example, positioned in front-end processing equipment which may be static or positionable in one or more dimensions.

One problem which occurs with respect to processing of such substrates is the detection of the actual position of the substrates to enable movement of the substrates from the carrier or front end set-up through the processing steps. In this disclosure, the term "actual position" refers to the position and orientation of a body (substrate or wafer) in space. The principles with respect to detection of a wafer in a field of space are not limited to the detection of a semiconductor wafer in a cassette, but are useful in any material manufacturing utilizing a front end setup, a chamber, or in a transportation cassette, such as a SMIF pod.

Indeed, processing also requires knowledge of the position of the carrier if the carrier is not stationary, as well. Typically, the position of the carrier must be "taught" to the system through a manual adjustment of the robot (by hand or software

command) to properly position the carrier/substrate to robot relationship. Normally, the position of the substrate in the substrate holder is determined by the known position of the substrate. The position of the carrier is "taught" to the robot by manually moving the robot arm to a position and informing the robot that this is the reference position, in which case the coordinates of the arms, links and motors of the robot are recorded. Up to now, when the carrier/robot arm relationship was taught, only the position of the wafer carrier (X,Y,Z) was set explicitly, not its orientation in space.

In conventional processing systems, only the existence of a wafer or substrate in a carrier is determined by automated scanning processes. Determining the existence of a wafer in a wafer carrier has conventionally been performed through the use of a sensor. Typically, wafer scanning may be performed using an optical sensor mounted on one of a robot's end effectors. Two typical sensor setups are shown in Figures 1 and 2, with a sensor 30 mounted on an end effector 32.

Typical sensors include light-emitting diodes or lasers, as emitters, and associated detectors for detecting the beam emitted by the diode or laser. The type and number of sensors on the end effector, and sensor readings, may vary.

In order to be useful, any detection scheme must determine the position of the substrate or substrate holder in space by finding: one or more characteristic points (planes or markers) of the wafer or substrate; and, in some cases, an Etalon substrate, a reference substrate precisely placed inside the holding device for reference purposes.

In prior art scanning systems, the purpose of scanning was to inspect the pockets of a wafer carrier for the presence and proper placement of wafers (wafers can be arranged in a holder in at least three configurations: normally inserted, cross-slotted, or protruding). This scanning task is fulfilled by a sensor equipped end effector when the robotic arm performs a scanning motion in front of the cassette. As shown in Figure 3, wafers 22, 23 and 24 will be found by a scanning element 104 while an empty pocket 25 will not be detected. Typically, the height of the pocket is known to the scheme, allowing the empty pocket to be determined.

In prior art systems, determining the actual position and orientation of a wafer

in three dimensions, as distinguished from the presence of the substrate in a substrate holder, has heretofore not been possible to accomplish with scanning systems.

Figure 4 is a block diagram showing a typical light-emitting diode (LED) and light detector (photo transistor) sensor. The light transmitting system is based on fiber optics in a single beam scanning type arrangement. As shown therein, the LED 40 emits a radiant wave 42 which reflects off the surface 44 of a wafer or other substrate to be detected, and the reflected wave is detected by the light detector 46 yielding a first data point.

When a sensor moves near to a wafer, the wafer edge reflects a light beam emitted by the LED. A fraction of the reflected beam is received by the light detector. The signal is detected (or latched) by the detection system and the pocket in the holder is marked as full. For purposes of this disclosure, a "pocket" is any space in a wafer carrier or other apparatus which is suitable of holding a wafer or substrate.

In a known scanning scheme, scanning motion begins at the base of the carrier or holding structure, and moves toward the top of the structure. During the scanning process, the sensors move in a predefined trajectory. Depending on the scanning mode, this trajectory may be of two types: the end effector moves up and down in a straight line in front of the cassette, typically known as "fast" scanning; or the end effector moves up in steps and pokes into each pocket, known as "slow" scanning. The motion path for scanning a given structure depends on the station parameters: the number of pockets, and the pitch (defined as the spacing of each given pocket), as well as the scanning mode and the start scanning position. The number of pockets and the pitch must be provided to each robot during the teaching phase for the robot. The start scanning position in the scanning mode may be chosen by the user of the robot.

It should be readily recognized that a substrate's position in the substrate holder will affect how scanning should be performed. Information on both the presence and the condition of the substrate in the holder pocket must be provided by the scanning procedure. During scanning, the position of a substrate will be examined with respect to substrate insertion and substrate orientation.

With respect to proper insertion of semiconductor wafer substrates, for

example, a wafer will have at least three types of orientations in a wafer holder: properly inserted wafers; cross-slotted wafers; and protruding wafers. Cross-slotted wafers are wafers that are badly inserted to the carrier, and hence occupy two or more adjacent pockets. Figure 5 shows a cross-slotted wafer 50 in a wafer carrier or other holding structure. Typically the available set of scanning commands in a conventional scanning system can automatically detect cross-slotted wafers that occupy neighboring pockets. For detection of cross-slotted wafers occupying more than two adjacent pockets, additional computations have to be made by the host software. Once detected, the carrier with a cross-slotted wafer requires manual intervention; that is, the robot can not process the cross-slotted wafer automatically. For the balance of this disclosure, the term "cross-slotted wafer" defines a wafer that occupies two neighbor pockets.

An example of a protruding wafer is shown in Figure 6. A protruding wafer is a wafer that is not fully inserted into the carrier, and, as shown in Figure 6, can represent an obstacle for the scanning motion of the robot arm.

Wafer orientation can also be of great importance in semiconductor wafers when the wafers have one or more "flats". "Flats" are common in semiconductor wafers and comprise a straight edge of an otherwise circular wafer. The possible orientation of the flat at several characteristic positions should be considered when tuning the scanning parameters. Different "flats" occur when a wafer or substrate is large enough that displacement occurs between the edge of the wafer and other portions of the wafer. There are at least four problems when considering scanning wafers with different flats: wafer displacement; wafer tilt; diameter loss; and scanning beam redirection.

Figures 7A-7C show wafers with a flat portion representing how X-Y axis displacement of the wafer in the holding structure 80 can occur. Figure 7A shows a wafer 70 without a flat in the wafer holder. The edges of the fully inserted wafer 70 contact portions of the wafer holder 80 and hence the wafer 70 is centered in the holder 80, i.e. the center point of the wafer holder 80 matches the center point of the wafer 70. In Figure 7B, an X axis displacement occurs. When a wafer flat 73 is present, and the wafer 71 may orient itself in such a way that its flat 73 comes up

against one of the insertion stoppers in a wafer carrier 80, the wafer shifts towards the insertion stopper. This movement causes a wafer displacement (dx, dy) as shown in Figure 7B or 7C.

When a wafer flat is present and a wafer is oriented in such a way that it is parallel to the pocket center line, the wafer 71 shifts towards one of the sidewalls and/or tilts. As shown in Figure 8, this wafer shift causes a dx wafer displacement, while the wafer tilt causes a dz wafer displacement (shown in Figures 7A, 8A and 8B).

Another problem exists when a wafer flat is perpendicular to a scanning end effector. when a wafer flat 75 is oriented towards the scanning end effector 82, as shown in Figure 9 (i.e., the flat is approximately perpendicular in relation to the end effector center line), the gap between the scanning end effector 62 and the wafer flat 75 becomes larger. In this case a wafer detection problem may occur because of the gap distance between the end effector and the scanning end effector.

Likewise, a problem may occur if the orientation of the flat 76 is other than perpendicular with respect to the end effector 62. Figure 10 shows yet another case where the flat is oriented toward the scanning end effector but is not perpendicular to the end effector center line. The beam is now reflected towards the receiver and the light detector cannot capture reflected light from the LED or other type of sensor. This problem can be avoided through a proper scanning sector setting.

SUMMARY OF THE INVENTION

The invention, roughly described, comprises a multiple point scanning system suitable for determining the orientation in space of a substrate such as a flat panel display or semiconductor wafer. The substrate, semiconductor wafer, or flat panel display may be positioned in the wafer carrier, and the system of the present invention can determine the position of the carrier, in order to calibrate and teach a positioning robot or other mechanism the position of the carrier. In contrast to the prior art which only determines the existence of a substrate in a carrier, the system of the present invention utilizes scanned data to determine the orientation of a substrate in space. This information can be provided to a positioning robot to retrieve the

substrate. In one set of embodiments, the vertical (Z axis) elevation and orientation of substrates is determined. In some embodiments, using top scanning sensors, X-Y coordinates of the wafer or substrate can be determined, and the actual position of the wafer calculated.

In one embodiment, the system comprises a dual-beam paddle-type scanning end effector, having a first and second emitter and a corresponding first and second detector. The end effector of the present invention may be utilized with an end eftector structure, the end effector structure having a first end and a second end, the first end including a forward scanning sensor, and the second end including top scanning sensors. The scanning end effector may be rotated about a Z-axis extending through a robotic arm, such as a global positioning arm, to position the scanning end effector relative to both the wafer holder and the substrates.

In a further embodiment, the scanning end effector is used with a rear scanning sensor coupled to a sensor frame. The sensor frame may be positioned along the Z-axis when an end effector engages the scanning frame and moves the frame along the Z-axis in conjunction with the scanning motion of the end effector.

In an alternative embodiment, the scanning end effector includes one, two, or three forward facing sensors and at least one back sensor.

In yet another alternative embodiment of the present invention, three sensors are located in a chamber or front-end set-up at three different locations in an X-Y plane, to sense the Z-axis coordinates of a substrate or wafer in a front-end processor which is positionable on an elevator or global alignment elevator. The system may be used in conjunction with a robotic arm or global positioning robot having one or more vertical detection sensors.

Each of the aforesaid mechanical embodiments may be utilized with one or more fast or slow scanning algorithms. In a fast scanning algorithm of the present invention, the end effector is moved along a vertical path parallel to the front of the substrate holder. In the slow scanning algorithm, the known pitch of the wafer carrier is utilized to position the end effector below the substrates positioned in the wafer holder and then insert the end effector into the substrate holder below each of the substrates to scan the surface of each of the substrates. Other algorithms, having

scanning motions similar to that used in the slow scanning algorithm, can be used to determine the X-Y coordinates of a substrate.

The invention provides the advantage of automating the calibration and teaching process utilized in positioning substrates, such as semiconductor substrates and flat panel displays, required in prior art embodiments. Moreover, the invention provides an efficient and novel means for determining the orientation of a substrate in three dimensional space in an automated fashion. This information can then be utilized by the positioning robot to handle the wafer or substrate. This advantageously allows for processing of "cross-slotted" wafers, which was heretofore unknown in the prior art.

These and other advantages of the present invention will be readily apparent to one of average skill in the art from a review of the attached disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described with respect to the particular embodiments thereof. Other objects, features, and advantages of the invention will become apparent with reference to the specification and drawings in which:

Figures 1 and 2 are top views of a single beam and double beam scanning end effector, respectively, in accordance with the prior art.

Figure 3 is a perspective view of the scanning process utilizing the prior art for determining the presence or absence of a wafer.

Figure 4 is a top level block representation of an optical sensor detecting the position of a wafer in accordance with the prior art.

Figure 5 is an end view of a cross-slotted wafer in a cassette.

Figure 6 is a side view of a scanning end effector showing the potential problem of the end effector engaging a protruding wafer in a cassette.

Figures 7A-7C are top views illustrating the problematic displacement of wafers having flats.

Figures 8A and 8B are top and side views, respectively, illustrating vertical displacement problems of wafers having flats.

Figure 9 is a top view of the diameter loss problem associated with wafer

substrates having flats.

Figure 10 is a top view of the light beam scattering problem associated with scanning wafers having flats.

Figures 11A and 11B are depictions of two different configurations of single beam end effectors.

Figures 12A-12C are representations of a scanning end effector scanning a wafer substrate to correct for the problem of light scattering.

Figures 13A-13C are top level depictions of a scanning end effector illustrating how scanning of a particular wafer with a horseshoe-type scanning end effector may be incorrectly performed by the end effector.

Figure 14 is a depiction of a double beam scanning end effector in accordance with the present invention.

Figure 15 is a perspective view of a first embodiment of the scanning apparatus of the present invention.

Figure 16 is a perspective view of a second embodiment of the scanning apparatus of the present invention in relation to a cassette and wafer under process.

Figure 17 is a perspective view of a third embodiment of the scanning apparatus of the present invention relative to a cassette and wafer system of the present invention.

Figures 18A and 18B are top and side views, respectively, of a first alternative of the embodiment shown in Figure 17.

Figures 19A and 19B are top and side views, respectively, of a second alternative of the embodiment shown in Figure 17.

Figure 20 is a reverse perspective view of the scanning apparatus shown in Figure 17.

Figure 21 is a perspective view of a fourth alternative embodiment of a scanning apparatus in accordance with the present invention.

Figure 22 is a side view of a wafer cassette partially loaded with semiconductor wafers depicting movement of a scanning end effector in accordance with the fast scanning algorithm utilized in the present invention.

Figure 23 is a representation of the fast scanning algorithm in accordance with

the present invention.

Figure 24 is a table showing the results of the fast scanning algorithm.

Figure 25 is a graph of the Z-axis positions of the scanned substrates relative to the pocket number found by the fast scanning algorithm of the present invention.

Figures 26A and 26B are side view representations of the fast scanning double pass algorithm utilized in accordance with the present invention, wherein Figure 26B is a close-up of the end effector adjacent to the wafer as depicted in Figure 26A.

Figure 27 is a side view of a wafer cassette and end effector illustrating the movement of the end effector in the slow scanning algorithm of the present invention.

Figure 28 is a top view showing an end effector a wafer cassette and wafers in the cassette, illustrating beam detection in the slow scanning algorithm in accordance with the present invention.

Figure 29 is a side view of a global positioning robot and global alignment elevator showing an alternative embodiment for positioning sensors in a stationary chamber or front-end set-up of a processing chamber in accordance with the scanning system of the present invention.

Figure 30 is a partial top view of the robot and elevator of Figure 29, illustrating the sensor configuration shown in Figure 29.

Figure 31 is a side view of an alternative embodiment of the invention shown in Figure 29 wherein a laser beam is utilized in accordance with a charge coupled device detector to determine the deflection of a given substrate.

Figure 32 is an enlarged side view of the Z-axis positions at which sensors may detect exactly placed wafers.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention defined herein includes a system and apparatus for scanning substrates in a holding structure such as a wafer carrier or other holding structure. Prior to the development of global positioning robots, as defined in co-pending patent applications Serial Nos. 08/661,292 and 08/788,898, positioning robots did not have the ability to compensate for inaccurate placement of a wafer carrier in three dimensions. To compensate, however, the control system must be aware of the actual

position of the carrier. Up to now, the position of the carrier was submitted to the system during a teaching process, which can include adjustment of the robot arm by hand or by using the robot's motion commands to a proper position inside the carrier. With the apparatus and scheme of the present invention, the teaching process can be automated through automatic scanning and decision making procedures. This eliminates the challenging and time-consuming teaching process, and user error in the teaching process through inaccurate data being submitted to the system during such process.

Moreover, the system of the present invention eliminates the need for multiple teaching processes. Generally, the data which is submitted during a conventional teaching process is only valid for the carrier which is being taught. After replacement of the carrier in the work process, the position of the new carrier does not always match the Etalon (or reference) carrier. Once taught, the robot cannot adapt to changing circumstances. Using the system and apparatus of the present invention, the automatic teaching system can accommodate many different types of work modules.

<u>End Effector Configuration</u>

Figures 11A and 11B show two scanning end effectors 100,102 for use in the system of the present invention. Scanning end effectors of the present invention may be classified into several different types: single beam end effectors, double beam end effectors, or triple beam end effectors. Within the group of single beam end effectors, two types exist: a horseshoe-type end effector 100 or a paddle-type end effector 102.

Figure 11A shows a horseshoe-type, single beam end effector 100 with a forward sensor (F.S.) to detect the presence of normally inserted wafers in the pockets along the X-axis, and a top sensor (T.S.) to detect protruding wafers which intersect the end effector in a vertical direction (along the Z-axis).

Figure 11B shows a paddle-type, single beam end effector with a top sensor (T.S.) and forward sensor (F.S.) at the same general location on the paddle. With the horseshoe-type end effector 100, the top and forward sensors are displaced from each other and from the center line of the end effector. In the paddle-type end effector

102, there is no sensor displacement between the center line of the end effector and either the top sensor or forward sensor. In general, tuning the scanning parameters of the paddle-type sensor is much easier, and the resulting scanning performance is better than the horseshoe-type effector. Horseshoe-type end effectors can exhibit beam scattering and, in certain cases, can prove unreliable in the detection of protruding wafers.

One potential error in finding substrates with a horseshoe-type end effector is illustrated in Figure 12A. When the longitudinal axis 122 of a horseshoe-type end effector 120 passes through the center of the water, as illustrated in Figure 12A, the scanning beam 124 is reflected by the wafer's edge away from the light detector. This can be avoided by rotating the arm 126 as shown in Figure 12B until the forward sensor (F.S.) points at the center of the wafer carrier, as shown in Figure 12C. (It should be recognized that the direction of rotation, clockwise or counter-clockwise, depends on the placement of the forward sensor on the left or right horseshoe end.)

Another potential error - - finding a protruding wafer in the wafer carrier is illustrated in Figure 13. In most cases, a protruding wafer will be detected by the top sensor in a scanning end effector. However, as shown in Figure 13, at some relative positions of a horseshoe-type end effector 130 and the wafer 134, the protruding wafer will not be detected by the top sensor. Figure 13A shows a fully inserted wafer which will be detected by the top sensor. Likewise, Figure 13B shows a protruding wafer that can be properly detected by the horseshoe-mounted top sensor. However, when the end effector 130 has the position shown in Figure 13C relative to a protruding wafer 134a, the wafer 134a will not be detected. This may lead to a collision of the upward-moving end effector 130 and the protruding wafer 134a. This problem can be avoided by selecting a slow scanning procedure as described in the Scanning Algorithms section of this disclosure.

Figure 14 shows one embodiment of a paddle-type end effector 140 of the present invention which comprises a double-beam scanning end effector. The double-beam scanning end effector offers fast and reliable wafer protection regardless of the wafer alignment and orientation. Two rectangular-shaped light sources and two optical sensors handle all wafer sizes with any combination of flats and notches. The

symmetrically-placed forward sensors 142,144 are positioned at opposing edges of a face 148. Face 148 has intersecting first 147 and second 149 surfaces joined at an angle on the center line 145 of end effector 140. The angle is selected such that the position of the forward sensors guarantees reliable operation when the wafer is positioned with a facing flat. Ideally, the angle is selected so that each forward sensor points to the center point of a wafer or substrate. This angle will vary based on the diameter of the wafer being scanned. Top scanning sensor 126 is positioned in the center of face 148 to provide safe avoidance of protruding wafers regardless of their orientation. End effector 140 shown in Figure 14 can scan all wafer sizes in a range from 3", to 300mm diameter wafers. Moreover, the difference between the end effector 140 of Figure 14 and those of the prior art is that the distance between the two forward scanning elements is greater than in previous embodiments, and optimized for the size of wafer with which it is to be used.

<u>Multiple Point Scanning Apparatus</u>

Determination of the orientation and position of the wafers inside a wafer carrying device is based on the sensor detection of the edges of the wafers in at least three points in space. The variance of this determination may include the placement, configuration, and number of the sensors on the end effector within a housing or other front-end equipment, and/or as mounted on a special frame, as disclosed hereinafter in accordance with the present invention.

Figures 15-20 show various sensor configurations on an end effector. Additional embodiments are shown which utilize a sensor mounting frame, suitable for use with the scanning end effectors shown in Figure 15, in accordance with the present invention.

Figure 15 shows a robotic arm structure 200 having a scanning end effector 210 positioned at one end of an arm 220. Arm structure 200 may comprise any of the robotic arm structures described with respect to the prior art, and in particular those arm structures disclosed in co-pending application Serial Nos. 08/661,292 and 08/788,998. Such arm structures are used in conjunction with the global positioning robot in application Serial Nos. 08/661,292 and 08/788,898, with the end effector

210, and all embodiments of end effectors hereinafter disclosed. When combined with the global positioning robots described in application Serial Nos. 08/661,292 and 08/788,898, the system of the present invention is well adapted to any number of processing applications.

End effector 210 includes a first end 232 having a horseshoe-type end effector structure 230, and a second end 242 including a front sensor structure 240. A rotational motor 232 allows the end effector structure 210 to rotate about an axis Z, in the first end 222 of arm 220. The horseshoe end effector 230 at first end 232 includes top sensors ST1, ST2 and ST3 for sensing along the Z-axis. A front sensor 243 is positioned at front end 240 of end effector structure 210. Sensors ST1-ST3 may be simple latched detectors - - enabling determination of the presence or absence of a wafer or substrate - - or may be proximity detectors, such as those commercially available from Honeywell, Inc., Honeywell Plaza, Minneapolis, MN. Figure 15 illustrates that with a single front sensor structure, the three data points (in X,Y,Z space) defining the position in space of a particular given wafer may be determined by three passes of the front end 240 over the wafers. As shown in Figure 15, in the first pass in a vertical Z direction, as illustrated by arrow 244, the end effector will detect a first forward facing (along the X-axis) data point on, for exaaple, a cross-slotted wafer 260 in wafer holder 205. A second pass 247, illustrated in shadowed form, will detect a second point on the cross-slotted wafer, and a third pass 249 (also shadowed) along the direction of arrow 245 will define a third point of cross-slotted wafer 260.

In the embodiment shown in Figure 15, the top sensors at end 230 of end effector structure 210 can be utilized to detect the distortion of large wafers over a wide range of wafer or substrate types. In one embodiment, where simple latch (presence) sensors are used, once the Z-axis portion of the edge of a wafer is known, and the size of the wafer is known, two or more edge points may be used to determine the center point (in the X-Y plane) of the substrate and the end effector positioned by the robot in the X-Y plane at the center point. As the activation distance of the sensor will be constant, the end 230 can be moved toward the center point of the substrate until the sensor is latched. The portion of the motors or other positioning means of

the robot controlling the end effector can then be used to determine the Z-axis deflection of the substrate. Alternatively, top sensors may be used which have the ability to detect actual positional distance from the sensor, or a scan across the surface of the substrate would then yield a deflection profile for the substrate.

The apparatus shown in Figure 15 demonstrates a single sensor, three point scanning algorithm. Examples of the scanning algorithms which may be utilized with the apparatus shown in Figure 15 are described hereinafter. One advantage to the two-ended structure shown in Figure 15 is that the first end mounting configuration of the top sensors allows the second end to scan the entire wafer in a single pass, while the horseshoe end can therefore be utilized for slow scanning as discussed below.

In an alternative embodiment (not shown), an end effector such as that disclosed in Figure 14 may be positioned at the second end of apparatus 210, eliminating the need for two ends as shown in Figure 15.

Figure 16 shows a three front sensor end effector structure 310 in yet another embodiment of the apparatus of the present invention. In Figure 16, three front sensors 312, 314 and 316 are positioned at the second end 340 of end effector structure 310. End effector structure 310 is structurally similar to structure 210 shown in Figure 15 and includes a first end 320 having top sensors ST1, ST2 and ST3 positioned in a horseshoe configuration in a manner similar to that of structure 210. Like structure 210, structure 310 is rotatable about an axis Z, and may be mounted on any number of robotic arms and elevator structures. With three sensors positioned at a given width along end 340, a single pass along the direction indicated by arrow 244 is necessary to establish three points of a given wafer in a wafer holding structure 205. The cross-slotted wafer shown in Figure 16 will be determined by establishing the three points in space as described below in the scanning algorithm section of this application. In prior art two-beam scanning systems, the two sensors were coupled by hardware means. To the control system, such dual beam systems of the prior art appear as a single beam scanner, only more reliable. In the end effectors of the present invention, each forward sensor operates independently, to determine a separate data point.

Figure 17 shows yet another embodiment of the apparatus of the present

invention wherein an end effector structure 410 includes a single front sensor 412 used in conjunction with a single back sensor 424 mounted to a movable sensor frame 450. Sensor frame 450 is positioned about wafer holder 205 (or any other holding structure), and the back 424 sensor is mounted to the frame structure.

Frame structure 450 may be positioned with respect to carrier 205 in a number of various embodiments. Figures 18A and 18B are top and side views, respectively, of one variation of the scheme shown in Figure 17, except that Figures 18A-18B illustrate use of an end effector 410a equipped with two forward sensors, rather than the single sensor shown in Figure 17. As shown therein, the rear sensor 424 and sensor frame may be mounted on a linear bearing 460 which allows movement of the frame up and down on the Z-axis direction as necessary. In the embodiment of Figure 18, the linear bearing is mounted to an immobile base, such as a work station or elevator. The frame has a shape (in Figure 18A - - a C-shaped cross-section in top view) positioned to surround the wafer holding structure 205. The exact shape of frame 450 is not of consequence as long as the rear sensor has line-of-sight access to the substrates. The end effector 410 or 410a includes a contact surface 454 positioned to engage the back sensor frame 450 at a frame contact surface 455 as necessary. Hence, the end effector 410a or 410 may move into position and raise and lower the sensor frame as necessary. An alternative embodiment of the rear sensor structure is shown in Figures 19A and 19B. In this embodiment, a linear bearing 460 for mounting frame structure 450 is mounted to the cassette or substrates, rather than to the immobile ground base. In the case of the linear bearing and frame being mounted to the wafer holder 205, as in Figures 19A and 19B, the sensor readings are relative to the cassette 205. In the case of the structure shown in Figures 18A and 18B, the readings of the sensors represent an absolute measurement. The positioning and configuration of the sensor frame 450 may be varied in accordance with the present invention without departing from the scope of the present invention.

Figure 20 shows an alternative perspective view of the end effector structure shown in Figure 17 with a back sensor mounted on a bearing which itself is mounted to a permanent structure, such as the ground, a work station, or other immobile base structure. Figures 17 and 20 illustrate the first pass of the single sensor end effector

structure 410 in bold lines, and the second pass in shadowed form, consistent with the depictions of previous embodiments. As will be readily understood, two points of the cross-slotted wafer, for example, will be detected by front sensor 412 and back sensor 424 on the first pass, while front sensor 412 will detect the third point in space on its second pass.

Yet another alternative embodiment of the end effector structure of the present invention utilizing a back sensor frame is depicted in Figure 21. End effector structure 510 includes two front sensors 512 and 514, and a back sensor 524 mounted on a sensor frame 550. As should be readily understood, the sensor frame configuration can be mounted to the wafer structure 205 or the immobile structure as described above with respect to Figures 18 and 19. In the example shown in Figure 21, the two front sensors 512 and 514 are more widely positioned than in end effector structures 210 or 210a, and detect two points of the cross-slotted wafer while the back sensor 454 detects a third point in space over a single pass along arrow direction 461. This greater width increases the accuracy of the structure shown in Figure 21.

Scanning Algorithms

A number of types of scanning algorithms are used with the scanning control software implemented with the robotic arm structures and positioning robot in accordance with the system of the present invention. These algorithms are generally denoted as "fast" scanning and "slow" scanning. The fast and slow algorithms differ not only in speed but also in the scanning motion of the arm and the way the data from the proximity sensors is processed.

In this disclosure, the function of the software will be hereinafter described. It should be apparent to one of average skill that these control functions may be implemented in any of a number of different manners (software, firmware, etc.) within the scope of the invention. Moreover, implementation of control software in conjunction with robotic arm structures are readily within the skill of a person of average skill. Hence, the specific code is not germane to the present invention.

During fast scanning, the end effector moves in a vertical straight line in front of the cassette. During the scan, samples from the Z-axis position of the detected

wafer are stored synchronously with the detection of a wafer by the forward sensor on the end effector. After the scanning motion is completed, the latched Z-axis values are processed. Based on the data points and the known values of the substrate holder, a decision is made about the presence and status (whether the wafer is normally inserted, cross-slotted, or protruding) of the wafers and the pockets.

This fast scanning motion is generally represented in Figure 22, which shows the scanning motion of an end effector 610. The data from the scan comes in a sequence of Z-axis coordinates. The number of samples is equal to the number of wafers present in the cassette or holding structure. The correspondence between samples and the nominal pocket positions must be established during training of the scanning system. The normal Z-axis coordinate of each pocket is calculated using the Z-axis coordinate of the first scan pocket and the known pitch of the pockets. In principle, when the sample value is near to the nominal Z coordinate of a given pocket, this is an indication that there is a wafer in the pocket.

Precise wafer detection is based on a procedure that takes into account the relative positioning of the sample within limits of the pitch as follows. The pitch is divided into "properly inserted area" and "cross-slotted area". The length of both areas is set by a scan slot (pocket) parameter in the control software. It shows the percentage of the properly inserted area with respect to the pitch. This is illustrated in Figure 24 where the scan slot parameter is set to 25%. The sample values are compared to the nominal slot positions, and the difference between the slot coordinates and the samples, denoted as A, is calculated and compared to the slot limit and the cross limit. A is calculated as follows:

Δ = (Pitch) x (CurrentSlot - 1) + StartScanPositionZ - ScannedPosition[current sample]

where:

Pitch = the pitch of the station;

StartScanPositionZ = the calibrated start scanning position for the Z-axis;

ScannedPosition[] = an array holding latched wafer positions in Z

coordinates; and

[current sample] = an index of the samples.

If the absolute value of Δ is smaller than the slot limit, then the wafer is considered "in the pocket". Further, if the opposite value of Δ is above the cross limit, the wafer is considered "cross-slotted". Finally, if it is below the cross limit, the wafer is considered properly inserted. When Δ is above the slot limit, the current pocket is considered "empty" and the scan sample as belonging to another pocket. The cross limit and slot limit parameters are calculated according to the following formula:

$$\text{SlotLimit} = (\text{Pitch} \times (1 - \text{ScanSlot}))/100$$
$$\text{CrossLimit} = (\text{Pitch} \times \text{ScanSlot})/100$$

As an example, and without limitation to the present invention, a cassette having five pockets and a pitch of around 0.1875" (Pitch = 187.5) is scanned. Four samples are gathered, i.e. four Z coordinates are latched during the vertical motion of the end effector. The scan slot parameter is set to 20%. The cross limit and slot limit parameters, specifying the properly inserted and cross-slotted area are calculated as follows:

$$\text{SlotLimit} = (\text{Pitch} \times (1 - \text{ScanSlot}))/100 = 1.875 \times 20/100 = 150$$
$$\text{CrossLimit} = (\text{Pitch} \times \text{ScanSlot})/100 = 250 \times 20 \div 100 = 37.5.$$

The processed results are given in the Table shown in Figure 24. The first column contains indexes of the slots, the second one contains the Z-axis coordinates of the slots, based on the calibrated start scanning position of the Z-axis. The third and fourth column contain the Z-axis coordinates of the upper and lower slot limits, respectively, for each pocket. The fifth and sixth columns represent the Z coordinates of the Z-axis positions at which the forward sensors were activated. The fourth column represents the difference between a theoretical wafer position and the actual latch coordinate (Δ). (All units are 1×10^{-3} inch.)

The fast scanning algorithm may have two implementations: a single pass

scan and a double pass scan. The algorithm described above is a single pass scan. Double pass scanning represents a sequence of two single pass scanning movements, one performed upward, the other downward with respect to the cassette or wafer holder. The second pass is performed only if no protruding wafers were detected during the first pass. Before moving down, the end effector is retracted slightly from the cassette, with the travel distance being specified by the user. The purpose of the second pass is to detect wafers that are slightly ejected from the pockets, but not enough to intersect with the scanner path and trigger the top sensor as shown in Figures 26A and 26B. Slightly protruding wafers may remain unnoticed during the first pass, when their edge is inside the dead zone of the sensor.

The active and dead zones of an exemplary forward sensor of the double beam end effector (such as that presented with respect to Figure 14 having LED-type sensors) are presented in Table 1.

Table 1: Forward Sensor Parameters

Forward Scanning Sensors Parameters	
Minimum distance to the wafer edge	0.500"
Maximum distance	1.200"
Recommended working distance	0.650"
Vertical range	<0.060"

These characteristics reflect performance of the scanner using 8" diameter wafers without flats.

The characteristics of single pass and double pass scanning, performed with the double beam end effector, are summarized in Table 2.

Table 2: Single Pass and Double Pass Scanning Characteristics

Scanning Procedure Parameters	Single Pass	Double Pass
Maximum wafer displacement (in any direction)	0.100"	0.200"
Typical scanning time (6" cassette, 25 wafers, 1"/sec)	9.2 sec	15.8 sec
Minimum scanning time (6" cassette, 25 wafers, 2"/sec)	6.3 sec	9.4 sec
Maximum scanning speed	2"/sec	2"/sec
Maximum number of wafers to scan	210	210

The above parameters represent the worst-case scenario: not aligned, non-oriented wafers with flats. The results can vary for different wafer edges on different process stages, and scanning speed and performance can be increased for cassettes with a wider pitch.

In contrast to the fast scanning algorithm, the slow scanning algorithm checks for the presence of wafers only at the calculated pocket positions. The advantage of the slow scanning algorithm, as compared to the fast scanning algorithm, is that cassettes with protruding obstacles may be scanned as well. When the arm is equipped with a single beam scanning end effector, only the slow scanning algorithm provides 100% reliable results. In this case, fast scanning may be used for a quick estimate and slow scanning for a precise estimate.

The movement of the end effector relative to a wafer holder in the slow scanning algorithm is represented in Figures 27 and 26. The motion of the end effector for scanning the pocket is performed in four steps:

1. The arm extends by a distance specified by the user and the end effector approaches the pocket. If, during the motion, the wafer is detected, the arm stops and retracts to the start scanning position and moves up a pitch to the next pocket. The following steps are performed only in the case a wafer is not detected during step 1:
2. The tip of the end effector moves on an arc in front of the cassette. This guarantees successful detection in case the flat of the wafer is

facing the scanner. The motion is performed by moving the Y-axis (for a robot equipped with a Y-axis) at a Z-axis (for robots equipped with Y-axis);

3. The arm retracts by a distance specified by the user; and
4. The arm moves up a pitch to the next pocket.

With the slow scanning algorithm and the detection along the Z-axis of the top sensors on the first end of the end effector structure 210,310,410, it is possible to determine the X-Y coordinates of the edge of substrates and if enough scans are made, the resulting X-Y data points, along with the Z-axis data points from the front end scanners, can be used to determine the actual position of the substrate.

Additional scanning algorithms are contemplated for use with the mechanical embodiments of the present invention. An algorithm to determine the X-Y coordinates of the edges of a wafer would include a scanning motion for the end effector first end having top facing sensors which would be similar to that of the slow scanning algorithm. However, in the slow scanning algorithms of the prior art, the positioning movement of the end effector and its relation to the carrier are known, so the only data to be determined is the presence of the wafer, which is known when the sensor activates. In the system of the present invention, a number of successive motions of the first end of the end effector would be necessary to determine the X-Y coordinates of the wafer or substrate, and the data points of activation of the sensor would be latched in a manner similar to the use of the data points in the fast scanning algorithms of the present invention. These data points would then be returned to the control system for the robot to calculate the actual position of the substrate in space to allow the robot to handle the wafer in accordance with the process desired.

Chamber Sensor Apparatus and System

Figure 29 shows an alternative embodiment of the scanning system of the present invention wherein at least some of the position sensors are positioned in a process chamber, or any front end process housing used in the processing of the substrates. This type of front-end chamber is more typically seen in processing of

large area substrates, such as flat panel displays.

Figure 29 shows a global positioning robot 700 which is made in accordance with the teachings of copending applications Serial Nos. 08/661,292 and 08/788,898. Front end set-up 710 can be any particular process chamber or front-end set-up. The front end equipment may, for example, include a global alignment elevator such as that shown in co-pending patent application Serial No. 08/661,292 or Serial No. 06/786,896. Both the global positioning robot 700 and the global alignment elevator 720 include the capability to adjust the Z axis motion of the robotic arm structure 722 or the cassette 730 in the system of the present invention.

Figure 30 is a top view of the sensor location shown in Figure 29. As shown in Figures 29 and 30, sensors S1-S3 are positioned on the walls of the chamber or front-end equipment. Sensors S1 and S2 are positioned on side wall 712, while sensor S3 is positioned on rear wall 714. This allows the three points of measurement for any given cassette and any given wafer loaded into the cassette. Because the global position alignment elevator 720 is able to move the cassette up and down, and back and forth, in the chamber, the cassette alignment and wafer alignment can be determined by three points which are given by the position of sensors S1-S3. If necessary, the robot can then be utilized to reposition the substrate into a correct position in the chamber or wafer holder. It should be readily recognized that the position of sensors S1-S3 need not be exactly as shown in Figure 29 and Figure 30. However, three points in space are necessary to define the position of a given wafer in the cassette. It should also be recognized that the robotic arm structure 722 must enter through a window 734 in the chamber 710 and positioning of the sensors must account for this necessity.

Additional vertical position sensors S4-S6 are positioned on a horseshoe-shaped arm structure 724 of the robotic arm structure 722. The end effectors 724 can move between adjacent wafers in the cassette or front-end set-up to determine the coplanarity of the wafers in the structure. Sensors Sl-S3 detect three (Z-axis) data points on the two sides of the wafer. This data determines the substrate orientation. The system shown in Figures 29 and 30 is particularly useful in processing of flat panel displays, which are rather large and have a vertical deviation between the edge

and the center of the substrate.

Sensors S4-S6 can also operate to determine the deflection between the edge and other portions of the substrate in the flat panel display. Because the size of the flat panel display is so large, there will be a difference in the deflection of the substrate. A given substrate of infinite stiffness is used as the reference point for sensors S4-S6. By measuring the edge vertical position, a laser or other type of sensor can measure the deflection distance. This embodiment is shown in Figure 31, wherein a laser beam source (not shown) outside the chamber can insert a beam 810 through window 734 against a detector or CCD 780 positioned on rear wall 714 of the chamber of front-end set-up 710.

It should be further recognized that sensors S1-S3 need not be utilized in the system of the present invention. If sensors S4-S6 are of a type to allow for the measurement of not only the presence of a substrate in the cassette, but also the Z-axis distance from the sensor, once the robot arm structure 422 is calibrated so that the position of the edge of the substrate is known, measurements of the Z coordinates relative to the position of the X and Y coordinates of the robotic arm structure 422 can be utilized to determine the precise location of the substrate. Sensors suitable for this purpose are commercially available from Honeywell, as described above. Once the robotic arm structure end effector 724 moves below the subject substrate, using a search procedure, the substrate can arrive at a position while all associated proximity sensors are activated. This can be done by reading the positions of the motors of the global positioning robot once the position of the platform and the position of the robot are known. Similarly, a scan over the entire surface of the substrate to determine the substrate's shape can be performed. The limitations of the accuracy of this scan will depend on the accuracy of the movement of the positioning robot and the movement tolerance of the robot.

The embodiment shown in Figure 31 can measure deflection to within 1/1000" of movement. When the end effector is on an object, the arm will deflect so that the reading will be the same until the actual deflection moves. The laser source should be positioned on the end effector to facilitate this measurement. Using this particular configuration, the robot can be self-calibrated for each of the objects in the chamber

or front-end set-up. Each payload will be generally the same amount of deflection, and deflection can be proportional to the load on the end effector. It should be further recognized that multiple lasers and multiple charge-coupled devices can be utilized in accordance with the teachings of the present invention.

Calibration

As noted above, the specific apparatus utilized in the present invention allows for automatic calibration and teaching of the robot of the present invention. It should be recognized that the scanning technique and system of the present invention are generally allowed to be utilized with the robots defined in co-pending applications Serial Nos. 08/661,292 and 08/788,898.

Normally, in the prior art, obtaining a Z-axis position of the robot where an ideal horizontal plane or wafer triggers the sensors in the set-up is the goal of calibration. If the sensors are properly mounted, all sensors should be triggered at the same Z-axis position. In practice, these readings would be different for each sensor.

This is illustrated in Figure 32. Suppose the first sensor is positioned at a position Z1 and the second at position Z2, and the third at position Z3. During scanning operations, the readings of the sensors Z1', Z2', Z3', respectively, are subject to correction under some calibration scheme. An example of such a scheme is the following:

$$Z1' = Z1' \text{ (not corrected)}$$
$$Z2' = Z2' + (Z2 - Z1)$$
$$Z3' = Z3' + (Z3 - Z1)$$

The goal of calibration in the present system is to ensure that one knows the Z-axis positions at which different sensors detect an ideally horizontal (Etalon) wafer. These positions are generally not the same, and all that is required is that one know the distance they differ.

Where top sensors (ST1-3), such as those shown in Figure 15, are provided in the dual-end end-effector, using a number of scanning passes of the first end of the

end effector under the wafer or substrate, one can determine the actual position in space of the wafer or substrate. A number of X-Y data points, and the diameter of the wafer or substrate, must be known in order to make this determination.

While in some embodiments, position edge points of the wafer in X-Y space can be determined, it is also possible to manually provide the position of the reference wafer to the positioning robot. Even though the orientation and Z-axis position can be determined automatically, the pick-up position of the reference wafer can be provided to the robot in order to yield the X-Y coordinates of other wafers in the carrier.

The start scanning positions, which are required in the prior art, may or may not be used in the system of the invention depending on the algorithm used. In general, however, if desired, such positions may be utilized. Normally, start scanning positions specify the robot coordinates where the scanning sensors detect the middle of the first wafer edge. For a fast scanning algorithm, there are anywhere from one to three scanning trajectories for each cassette. They represent the vertical straight line starting at three different start scanning positions. To properly teach the start scanning positions, a wafer is placed in the first pocket of the cassette. The end effector is then positioned exactly against the edge of the wafer by moving the robot using motion commands in the control software to a distance of approximately 0.650" along the longitudinal axis of the end effector. The position of the start scanning position can then be set.

It should be recognized that using a vertical position sensor and a horizontal position sensor as described above in the apparatus of the present invention, the actual position of the wafer cassette holder can be automatically determined by the apparatus of the present invention.

The robot must be programmed with the specifics of any particular cassette or substrate holder's size. Parameters such as the distance at which the end effector retracts before starting the second pass in the double pass scanning can also be set in the system of the present invention. Additional parameters which may be set include the scanning speed, and scanning acceleration.

Double-pass scanning may also be used to cope with the situation where the

scanning end effector is too close to the substrate and the dead zone exists. In this case the end effector must be retracted and a second pass made to ensure accuracy.

A scanning system and apparatus for scanning multiple substrates in a substrate holder, such as a cassette, has been described. Multiple embodiments of the apparatus and system of the present invention have been described as being within the scope of the present invention. It should be recognized by one of average skill in the art that numerous other modifications, and variations and combinations of the position of the sensors, the locations and techniques of scanning, can all be utilized within the scope of the present invention. The present invention is necessitated and made possible by the use of the robotic arm structures having a global positioning capability (i.e. the ability to manipulate the Z-axis of the robot) described in co-pending applications Serial Nos. 08/661,292 and 08/788,898. However, the present invention is not limited to global positioning robots, but may be used with any arm having enough degrees of freedom. All such modifications and changes to the invention are considered as being within the scope of the present invention as defined herein, and as defined by the following claims.

CLAIMS

What is claimed is:

1. A system for detecting the position of a substrate in a substrate holder, comprising:

means for detecting at least three points of a substrate in space, each point having an X-Y-Z coordinate; and

means for controlling the position of the substrate in a substrate carrier responsive to said means for detecting said three points of the substrate.

2. A method for detecting first, second, and third data points to define a position of a substrate in space, comprising the steps of:

scanning, using a vertical position sensor, to determine a first edge of the substrate; and

scanning, using a horizontal position sensor to determine said first, second, and third data points.

3. An apparatus for detecting at least three points of location on a substrate in a substrate holder, comprising:

a first sensor, vertically oriented to determine at least a first data point indicating the position of the substrate in a direction along a first axis; and

a second sensor, horizontally oriented to determine at least a second data point indicating the position of the substrate by sensing in a second axis whether the substrate exists at given points along the first axis.

4. The apparatus of Claim 3, wherein the first sensor and the second sensor are mounted on a scanning means, the scanning means including means for positioning the scanning means in three-dimensional space.

5. The apparatus of Claim 3, wherein the scanning means includes a second sensor detecting positional data points along the first axis.

6. The apparatus of Claim 5, wherein the apparatus includes a third sensing means detecting positional data points along the first axis.

7. An end effector, comprising:

a first end including a front sensor for detecting a position data point of a substrate along a first axis;

a second end including a vertical sensor for detecting a second data point of a substrate along a second axis;

means for positioning the end effector in three dimensional space; and

means for rotationally mounting the end effector on the means for positioning.

8. A scanning system, comprising:

an end effector having at least one sensor capable of detecting a data point by reflecting the position of a substrate along a first axis; and

a process chamber including sensing means for detecting at least one data point of the position of the substrate along a second axis.

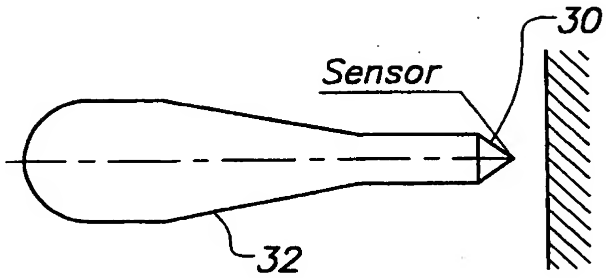


FIG. 1

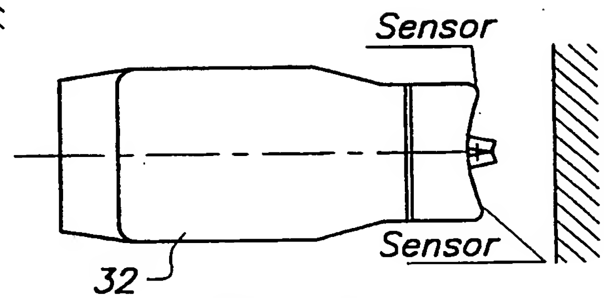


FIG. 2

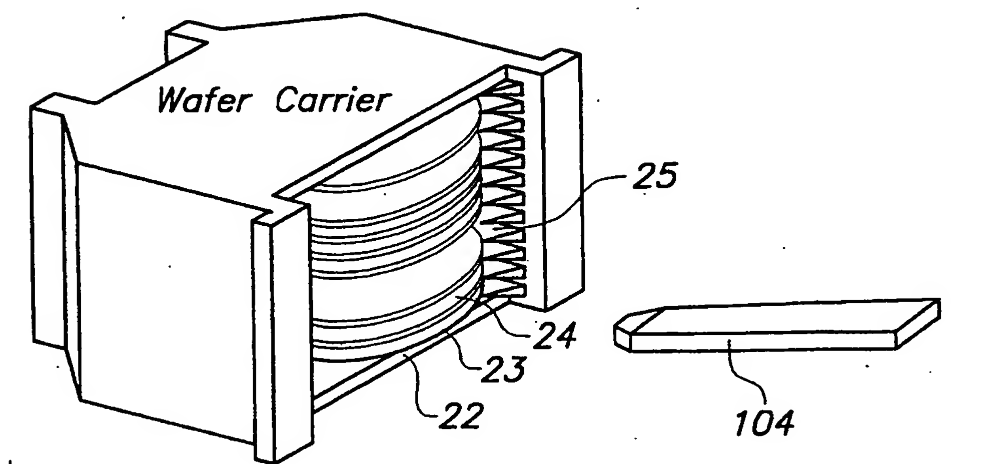


FIG. 3

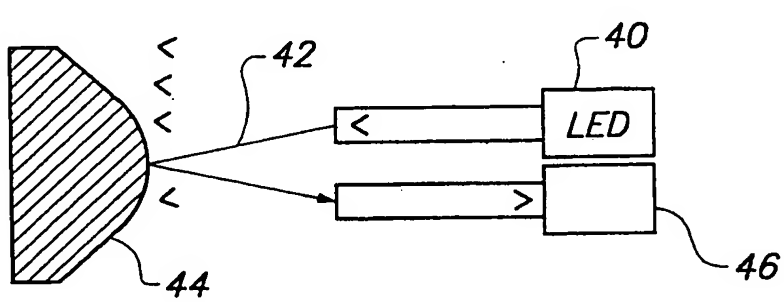


FIG. 4

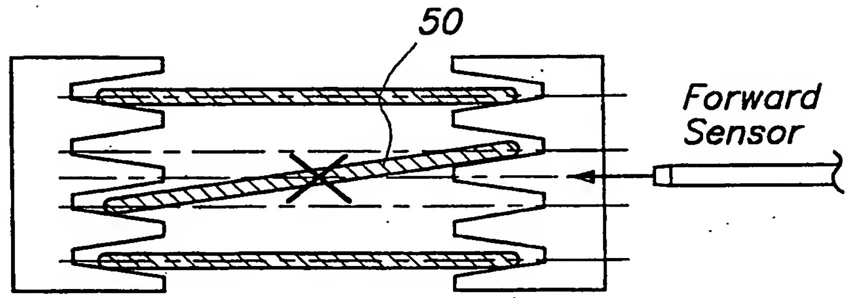


FIG. 5

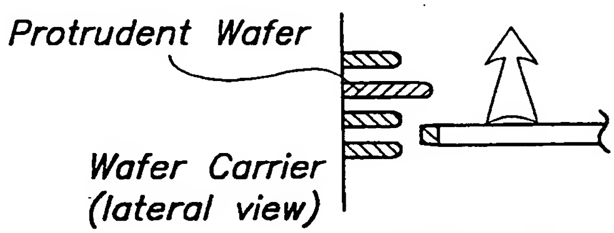


FIG. 6

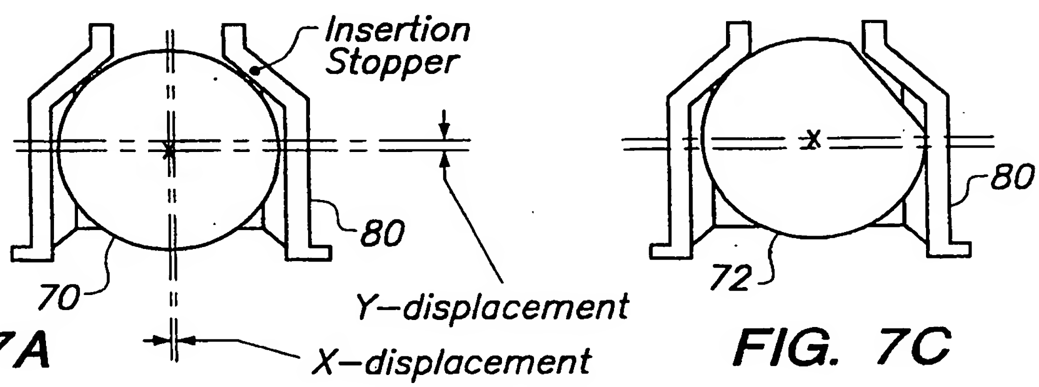


FIG. 7A

FIG. 7C

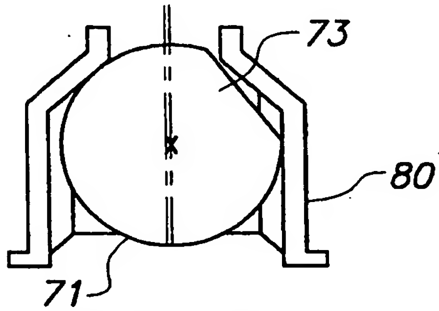


FIG. 7B

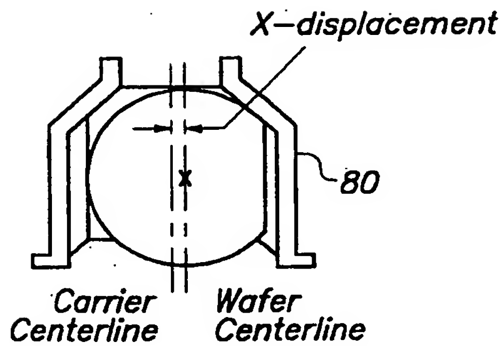


FIG. 8A

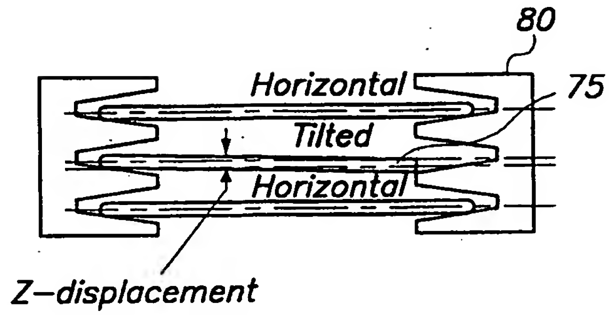


FIG. 8B

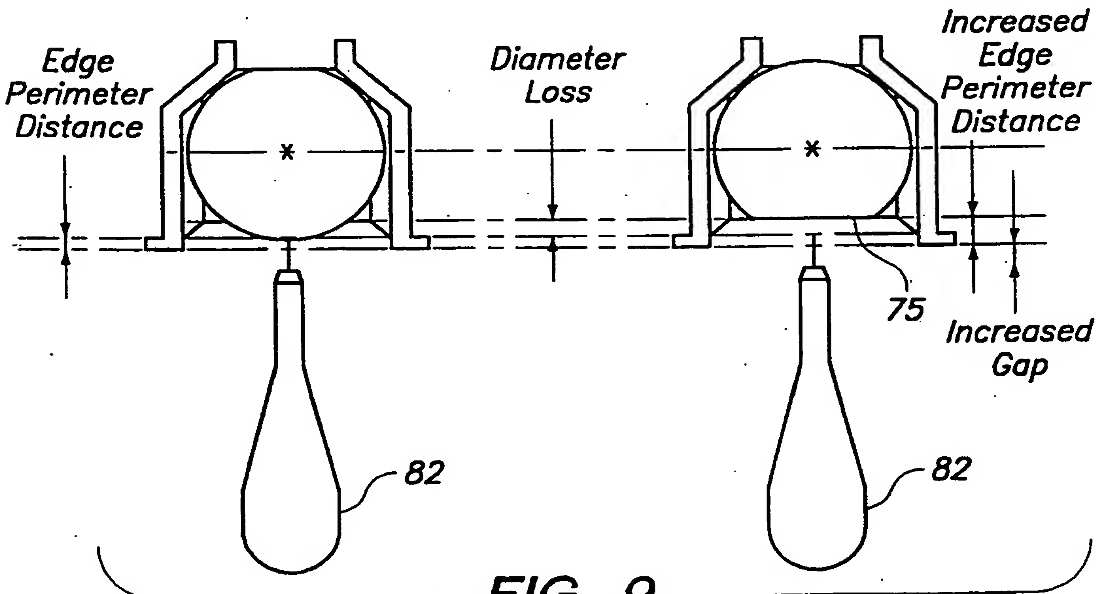


FIG. 9

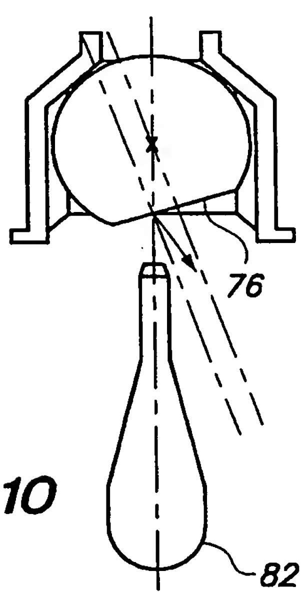


FIG. 10

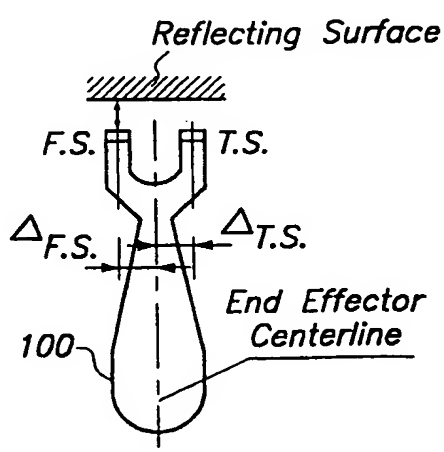


FIG. 11A

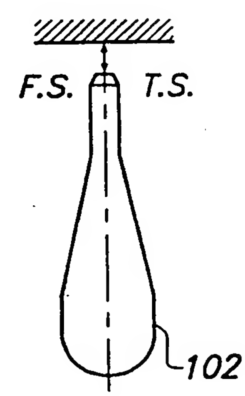


FIG. 11B

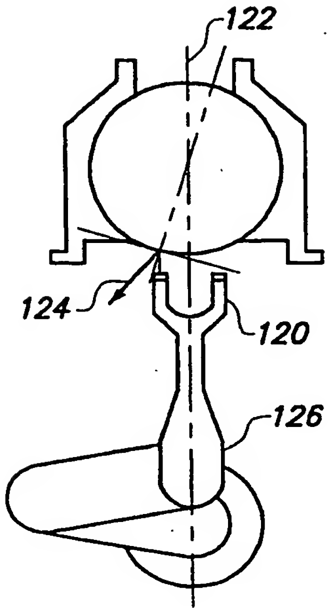


FIG. 12A

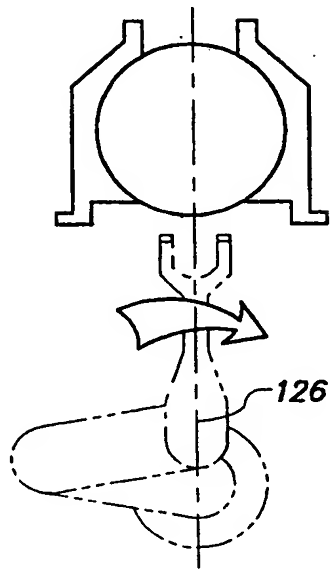


FIG. 12B

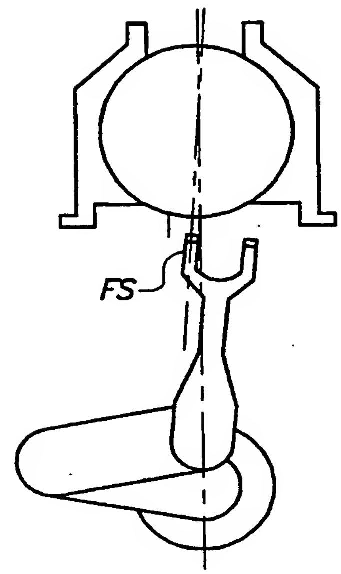


FIG. 12C

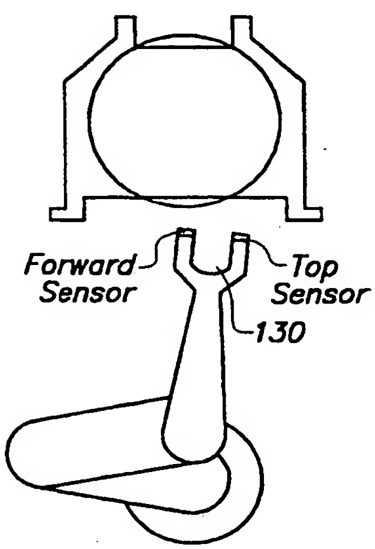


FIG. 13A

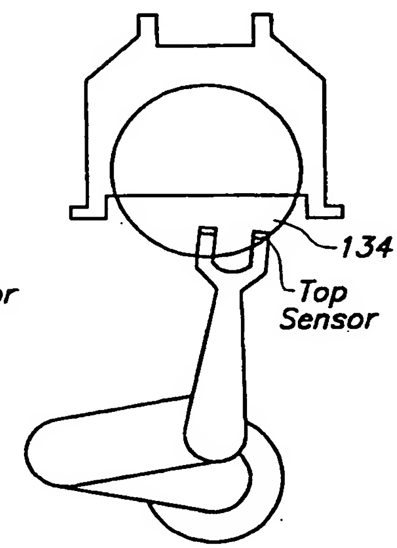


FIG. 13B

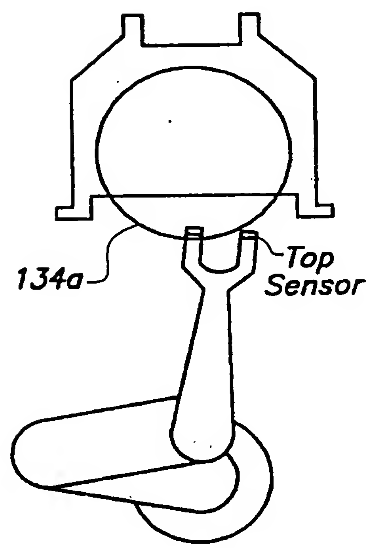


FIG. 13C

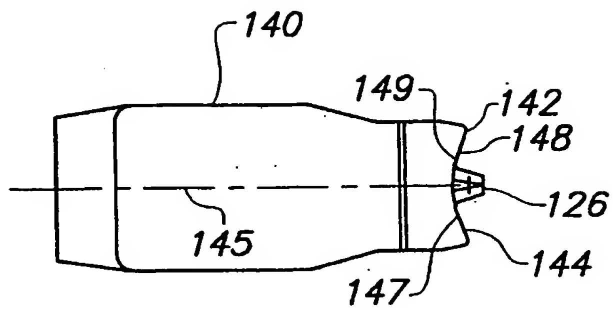

140
149
142
148
126
145
144
147

FIG. 14

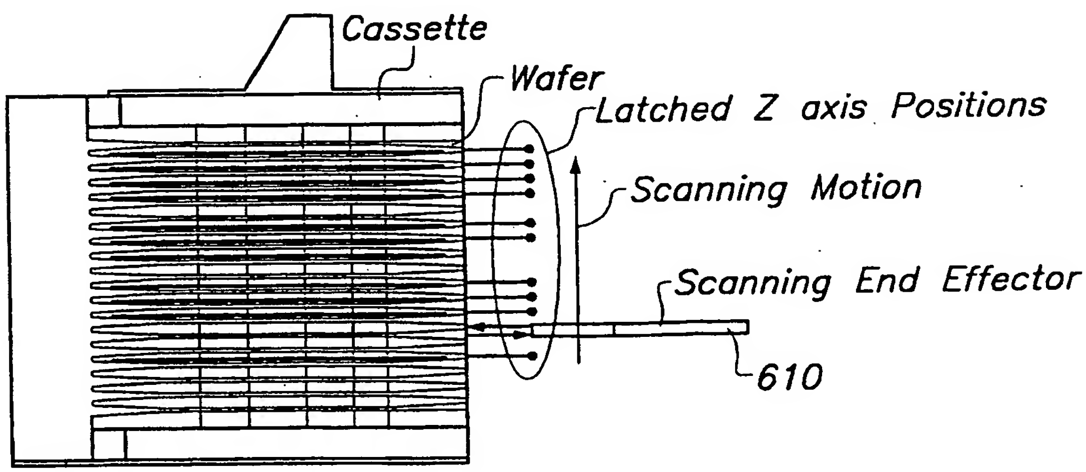

Cassette
Wafer
Latched Z axis Positions
Scanning Motion
Scanning End Effector
610

FIG. 22

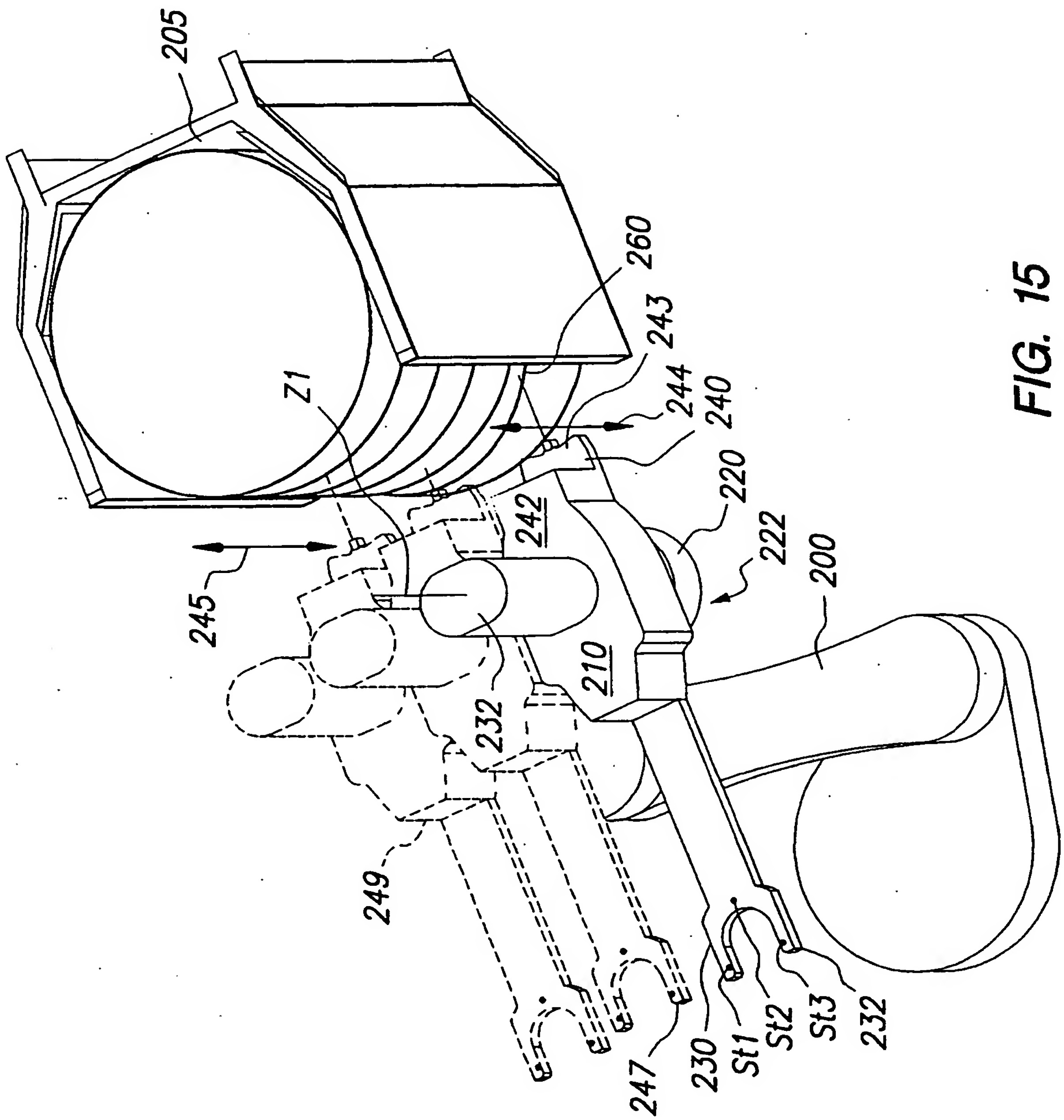

205
260
243
244
240
Z1
220
222
200
242
245
210
232
249
247
230
St1
St2
St3
232

FIG. 15

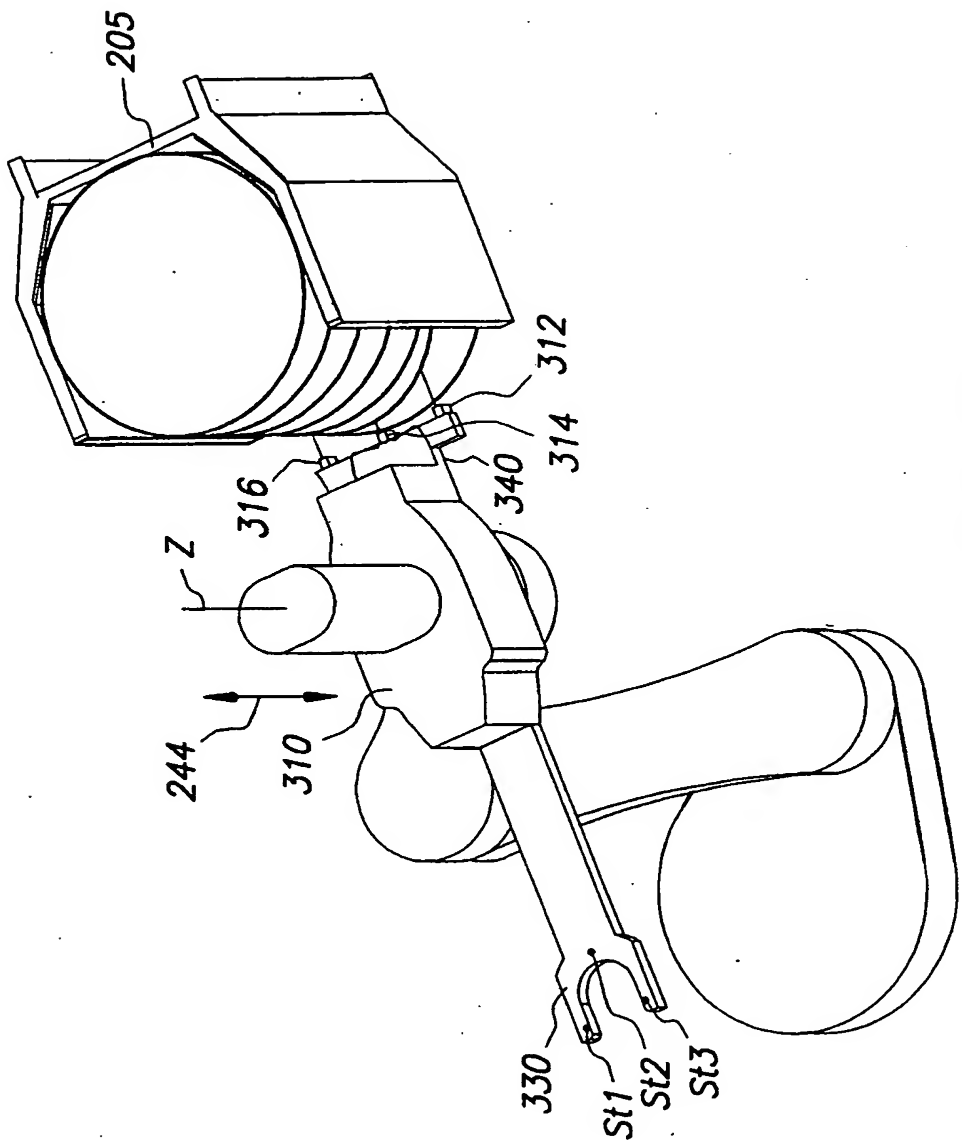


FIG. 16

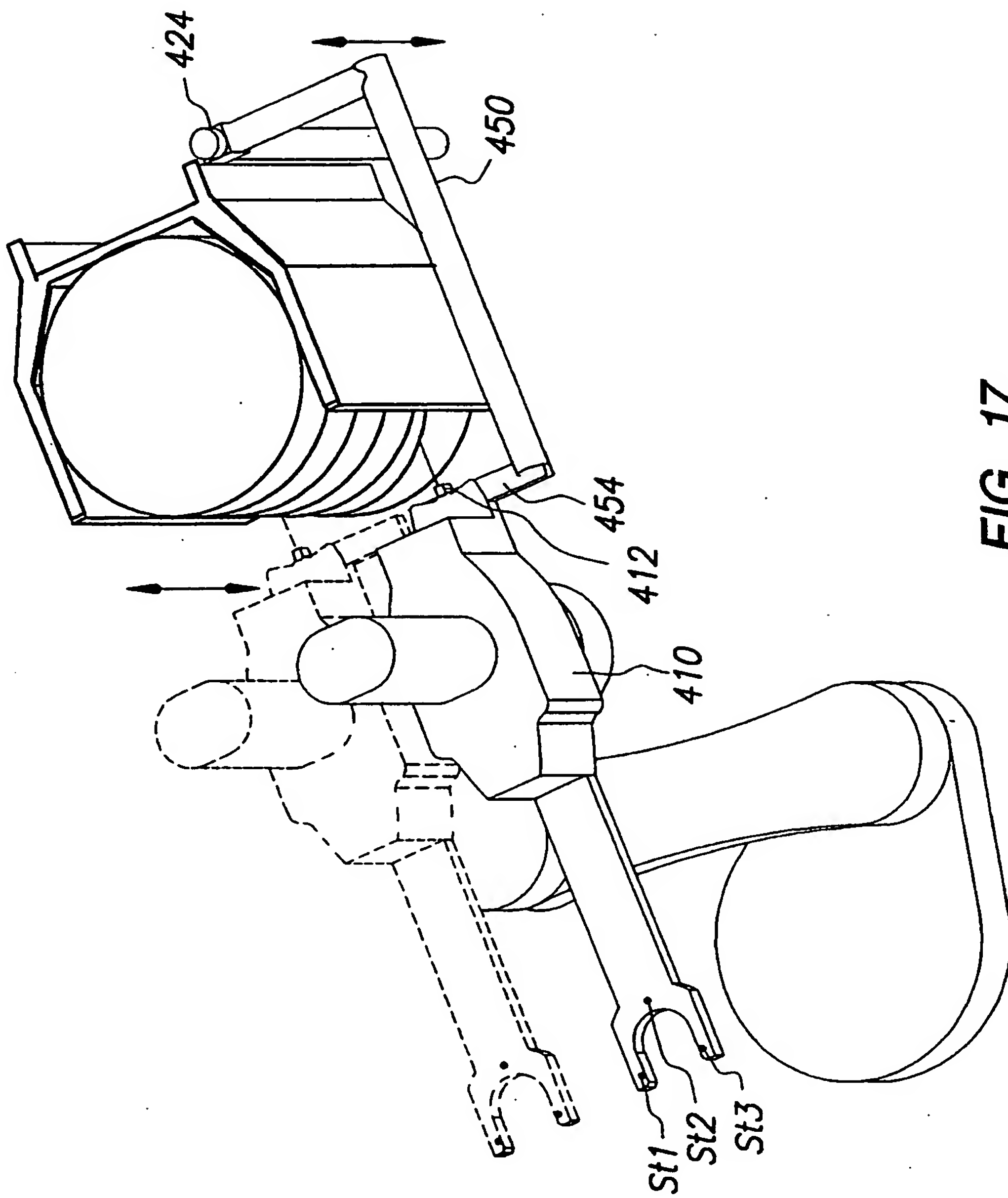


FIG. 17

FIG. 18A

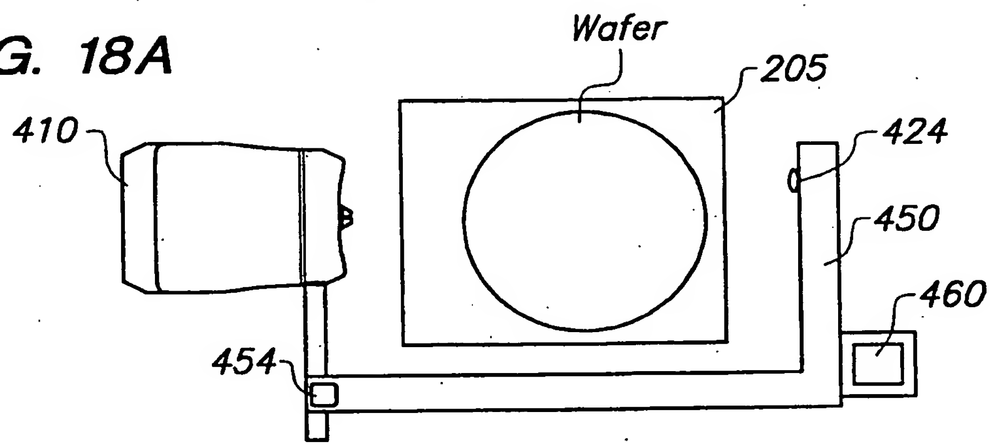


FIG. 18B

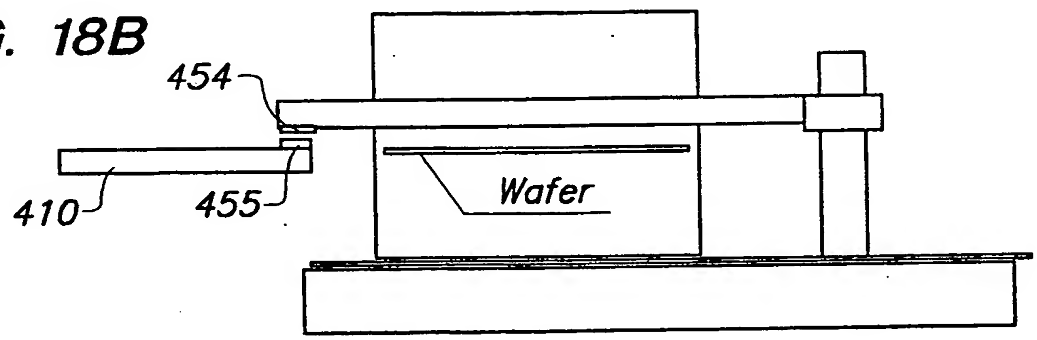


FIG. 19A

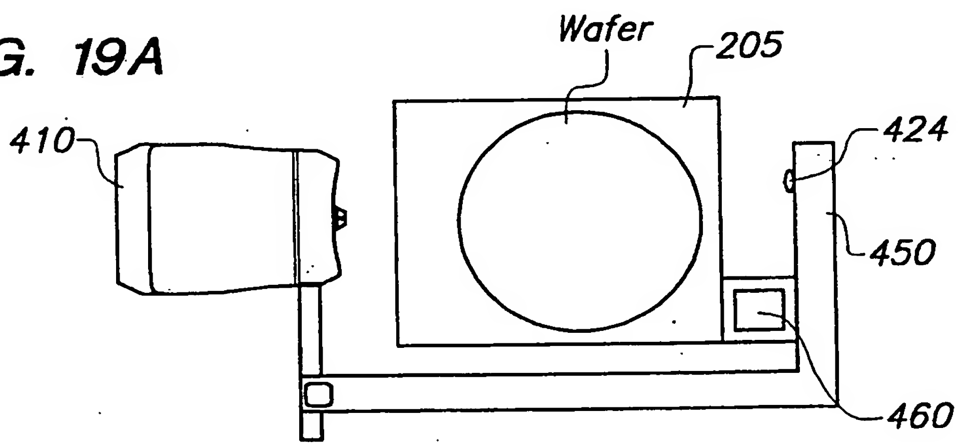


FIG. 19B

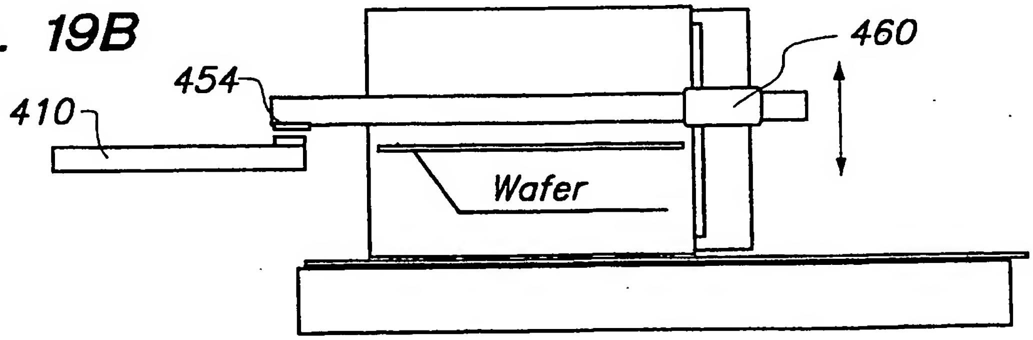
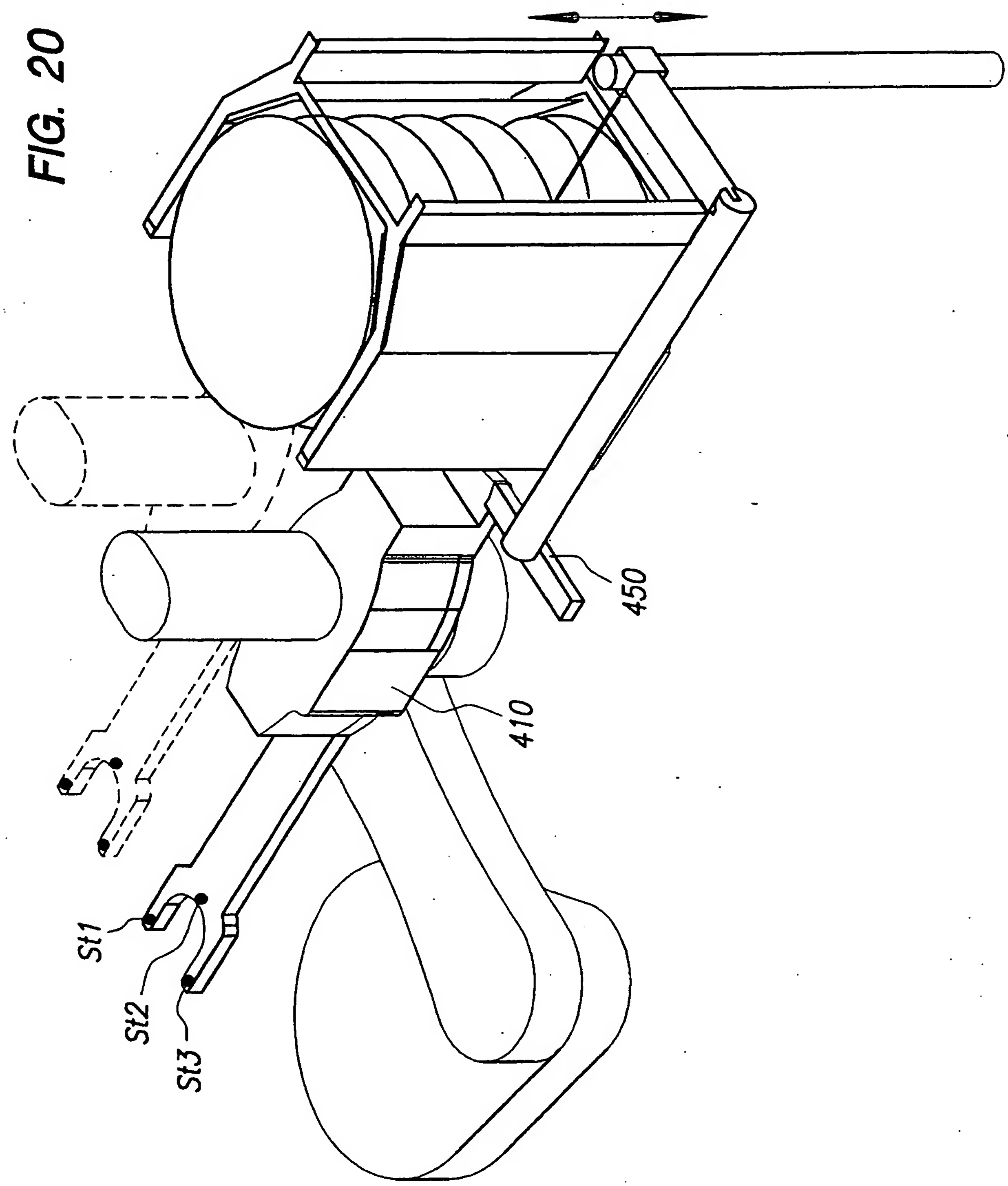


FIG. 20



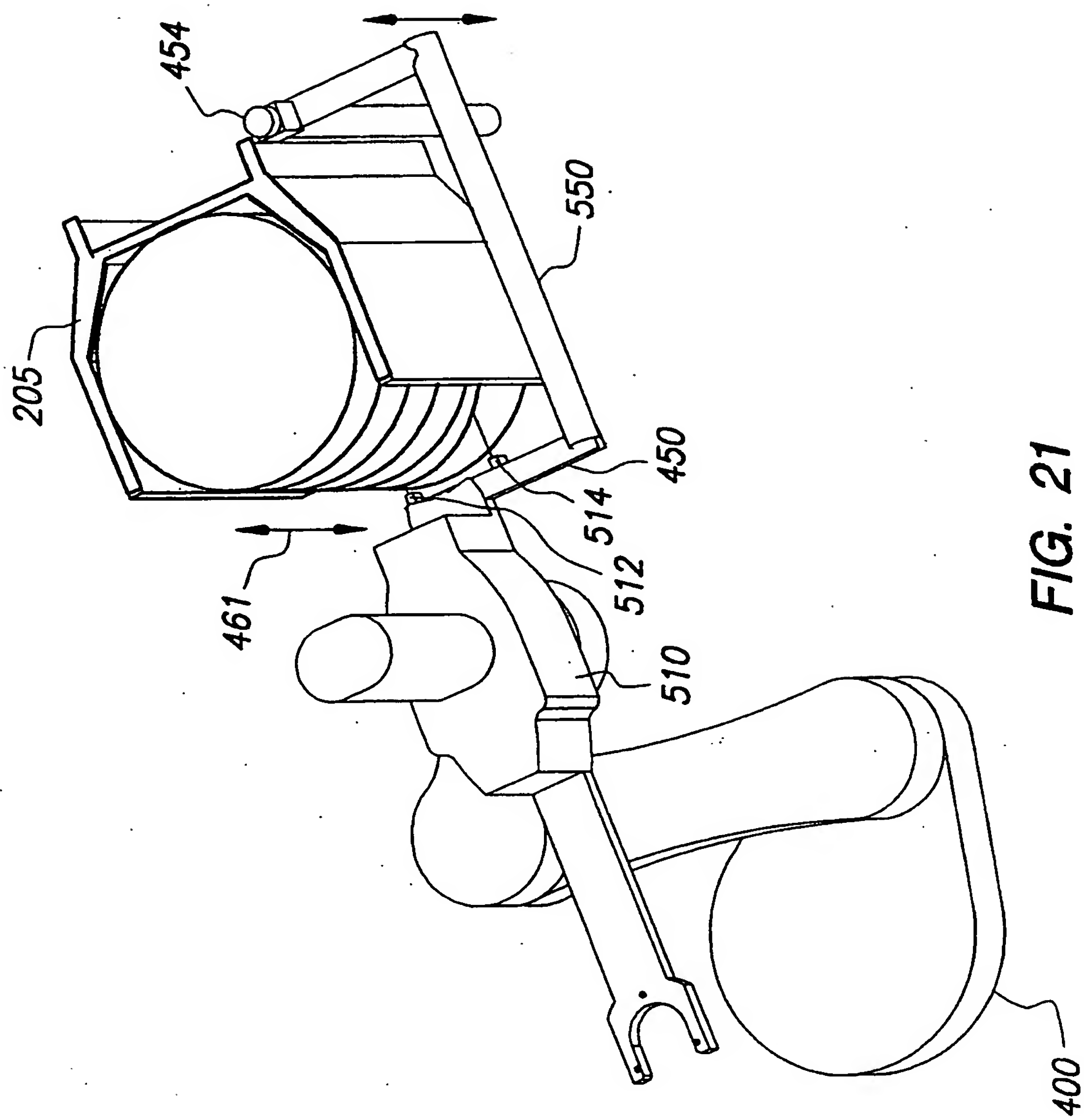


FIG. 21

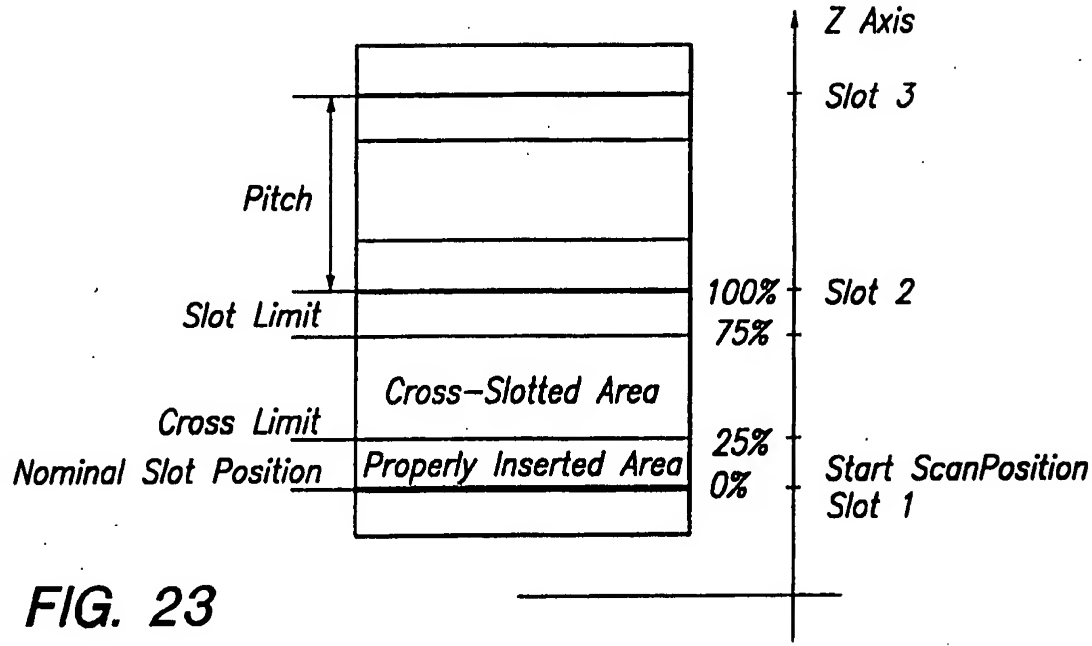


FIG. 23

Pitch	ScanSlot	Slot Limits		Cross Limit		Data	
187.5	20%	−150	150	−37.5	37.5		
Slot No	Nom. Pos.	Low Slot Limit	Upper Slot Limit	Low Cross Limit	Upper Cross Limit	Sample	Delta
1	130	−20	280	92.5	167.5	132	2
2	317.5	167.5	467.5	280	355	441	123.5
3	505	355	655	467.5	542.5	695	190
4	692.5	542.5	842.5	655	730	695	2.5
5	880	730	1030	842.5	917.5	876	−4

FIG. 24

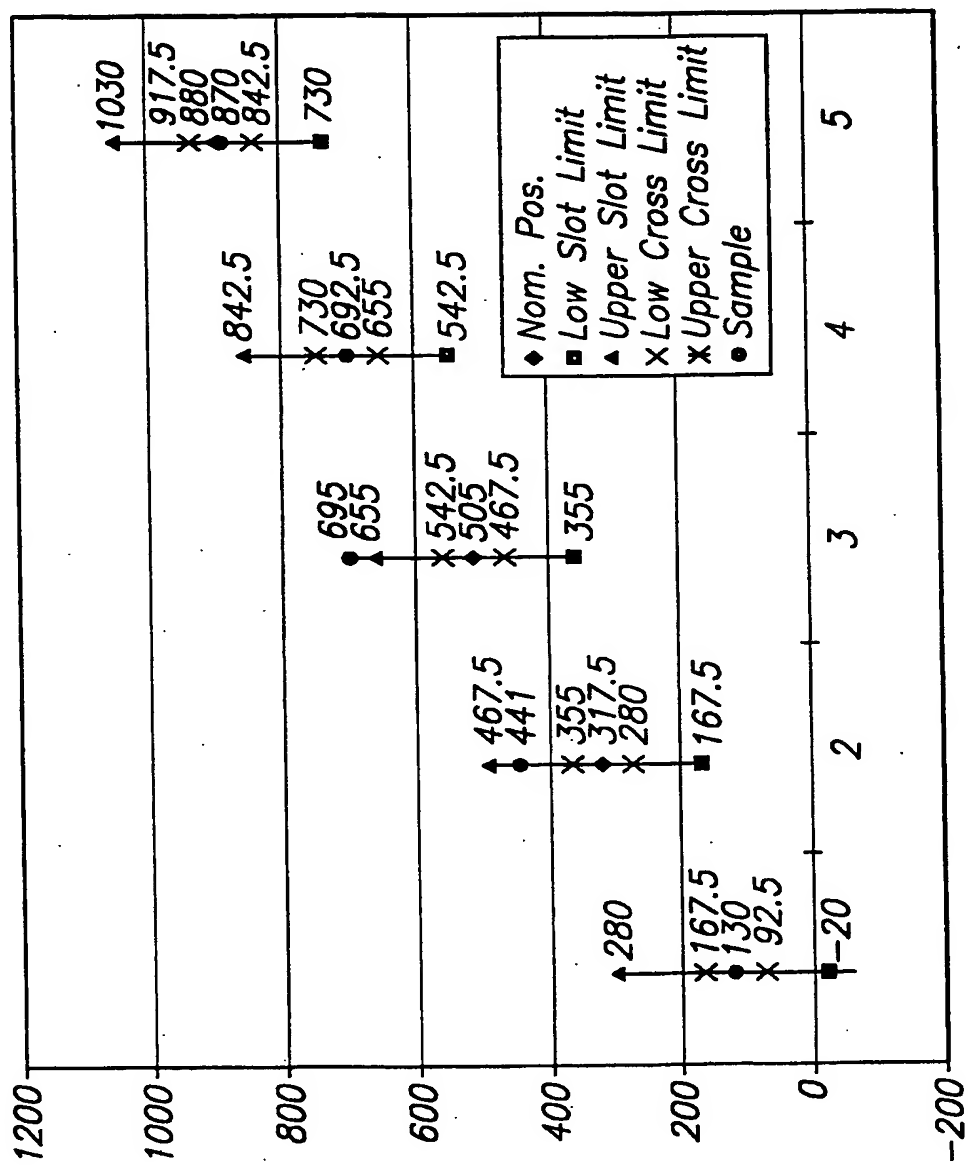

Nom. Pos.
Low Slot Limit
Upper Slot Limit
Low Cross Limit
Upper Cross Limit
Sample
1200
1000
800
600
400
200
0
-200
1
2
3
4
5
280
167.5
130
92.5
-20
467.5
441
355
317.5
280
167.5
695
655
542.5
505
467.5
355
842.5
730
692.5
655
542.5
1030
917.5
880
870
842.5
730

FIG. 25

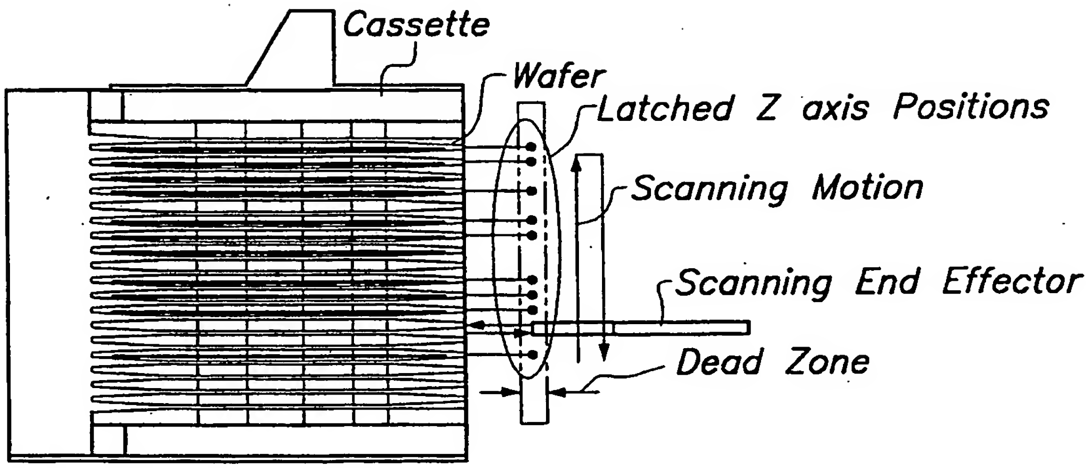


FIG. 26A

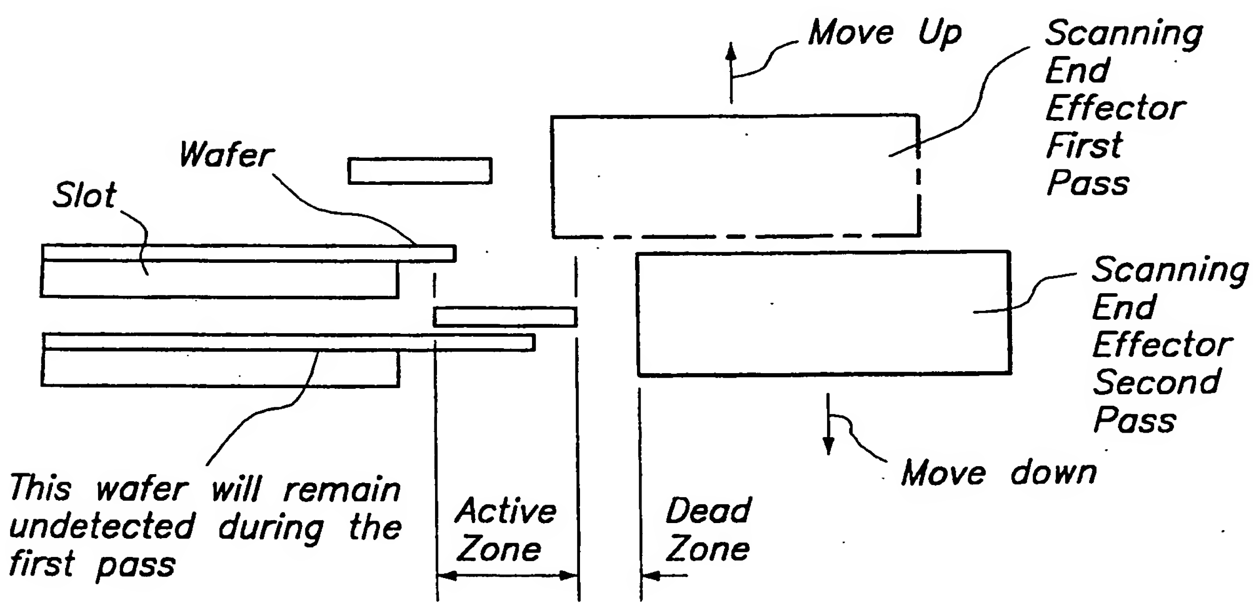


FIG. 26B

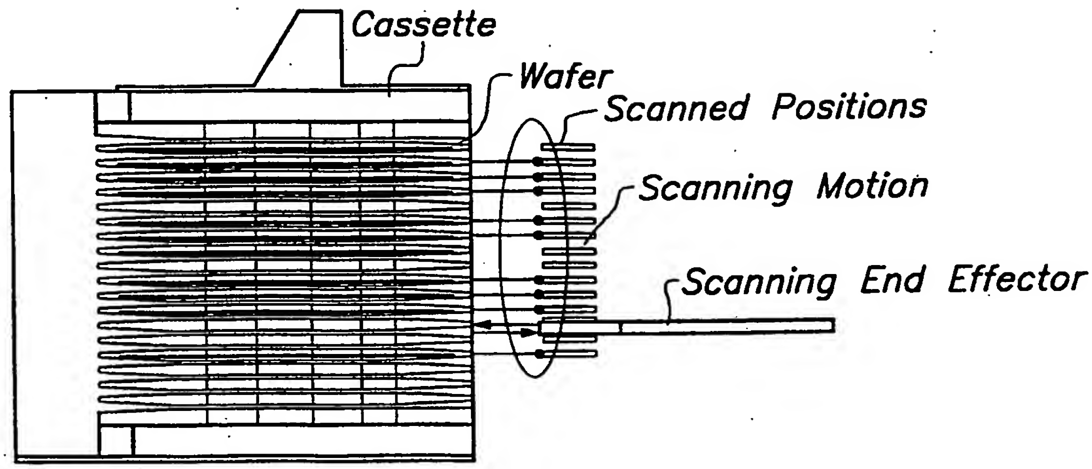


FIG. 27

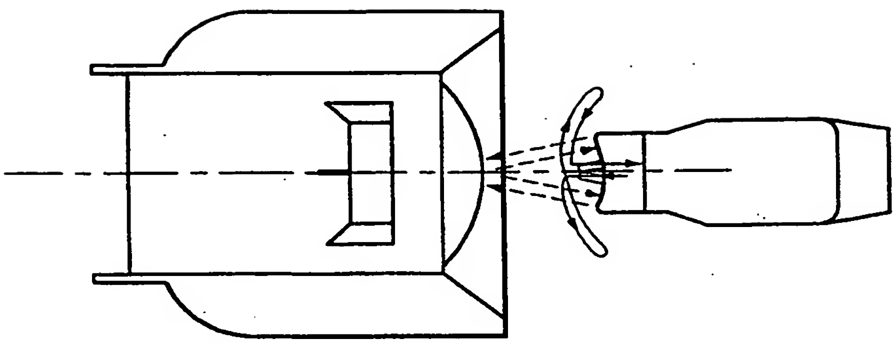


FIG. 28

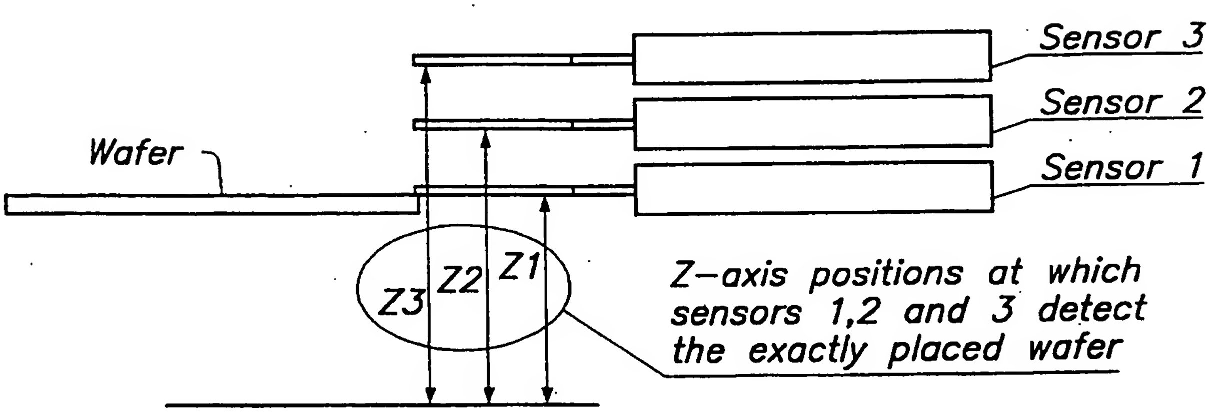


FIG. 32

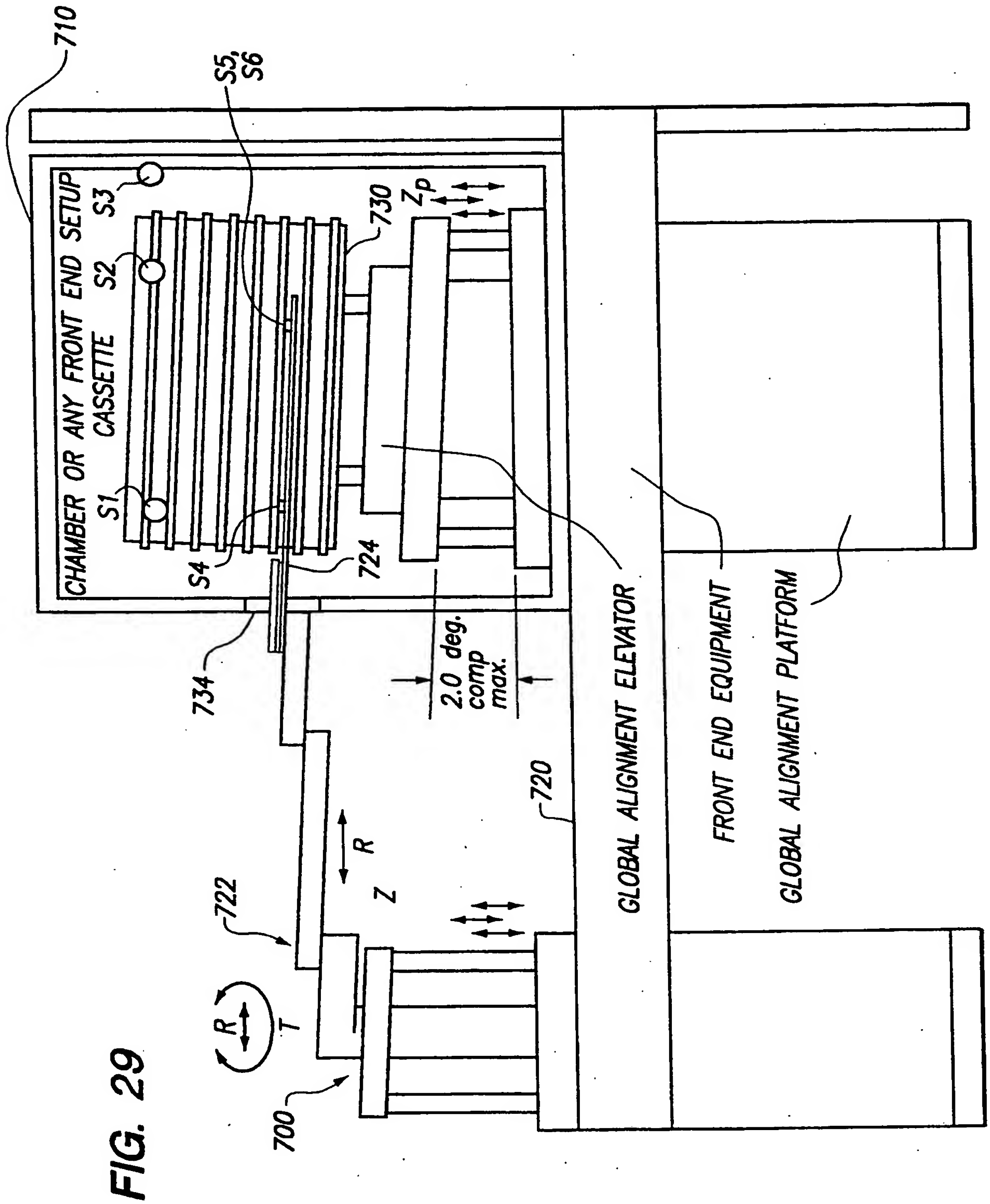

710
S5, S6
CHAMBER OR ANY FRONT END SETUP
CASSETTE
S1
S2
S3
S4
730
Z_p
724
734
2.0 deg. comp max.
GLOBAL ALIGNMENT ELEVATOR
FRONT END EQUIPMENT
GLOBAL ALIGNMENT PLATFORM
720
722
R
Z
R
T
700

FIG. 29

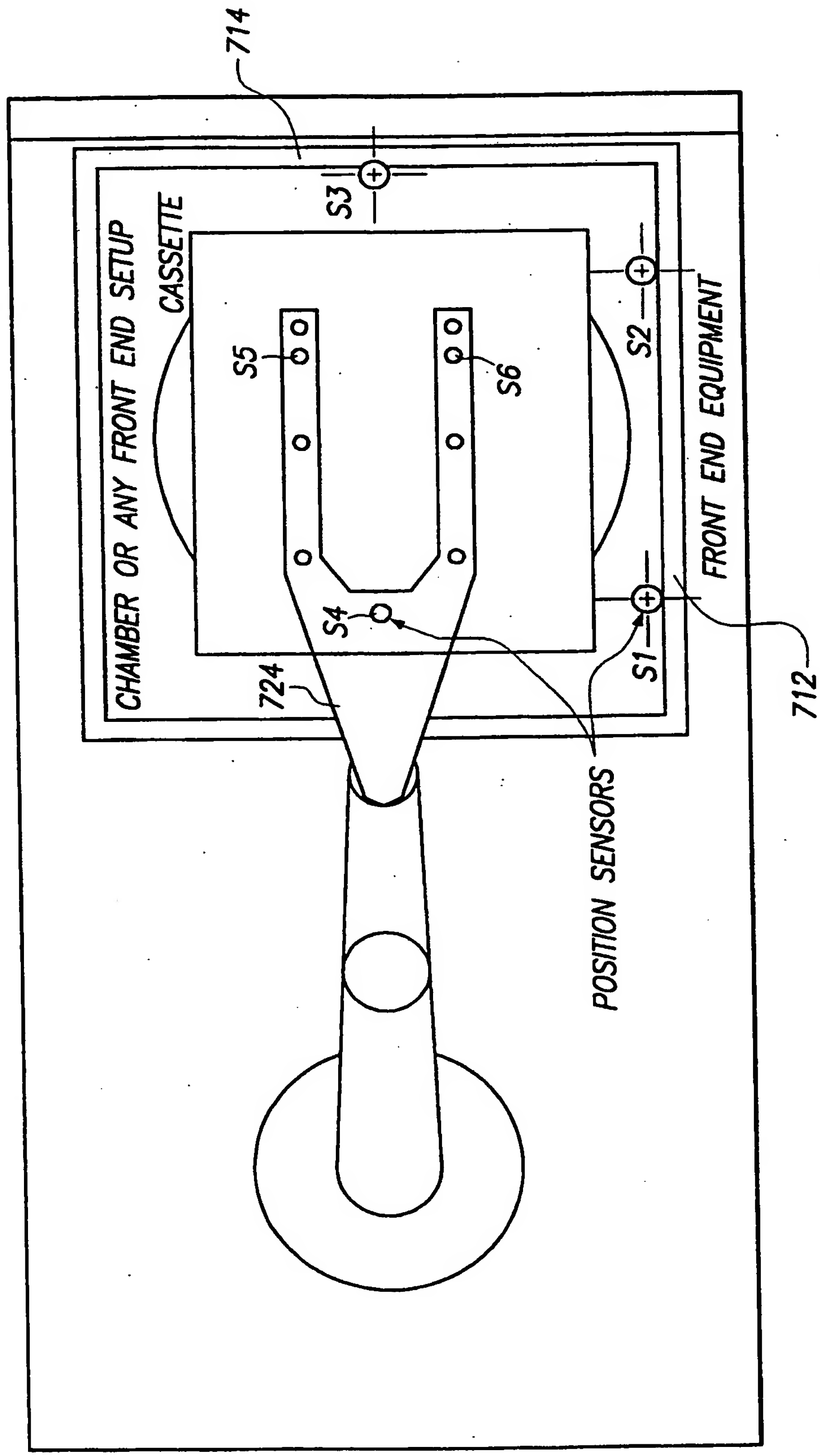

714
S3
CHAMBER OR ANY FRONT END SETUP
CASSETTE
S5
S6
S2
FRONT END EQUIPMENT
S4
S1
724
712
POSITION SENSORS

FIG. 30

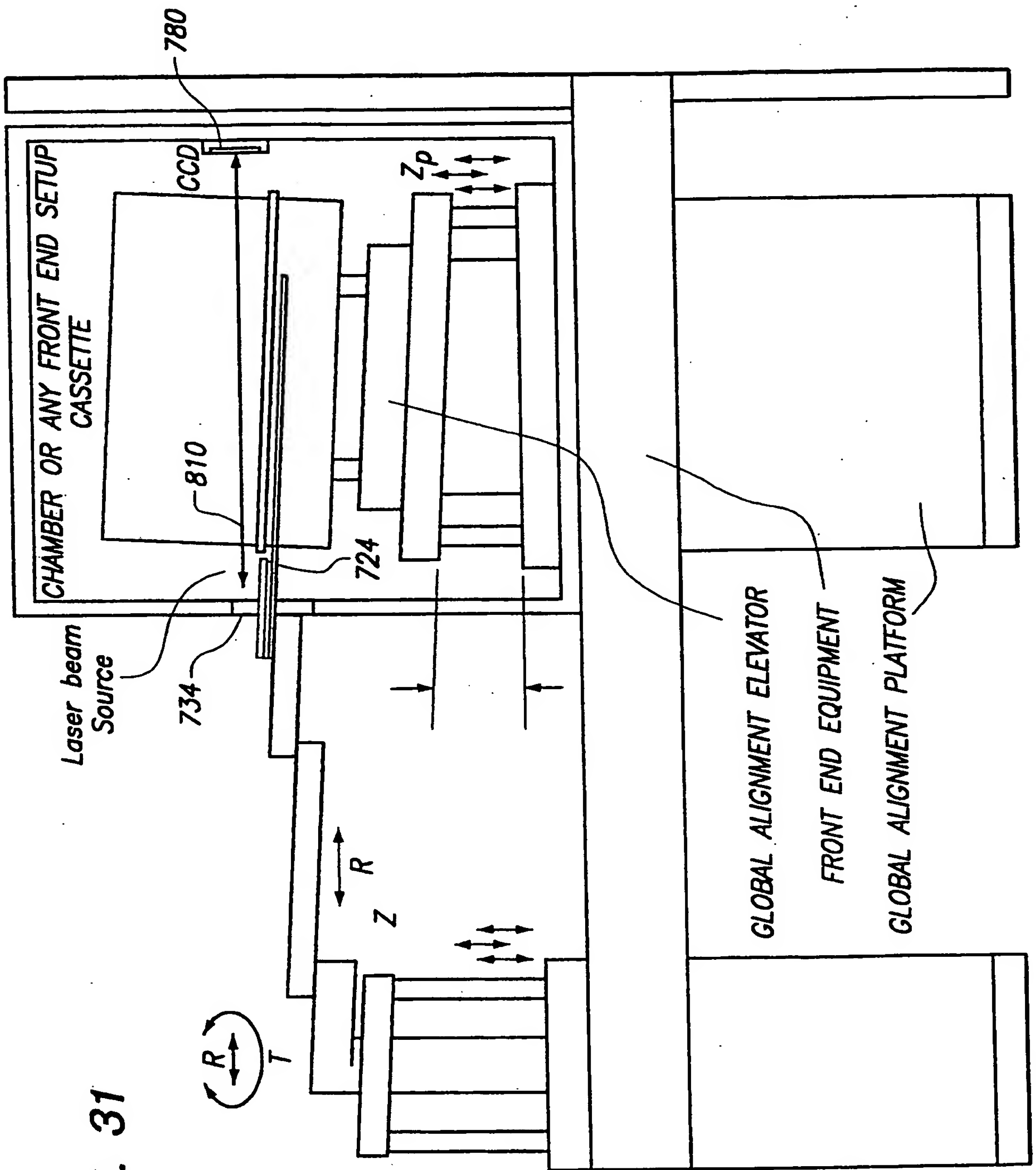

780
CCD
CHAMBER OR ANY FRONT END SETUP
CASSETTE
810
724
734
Laser beam Source
Z_p
R
Z
R
T
GLOBAL ALIGNMENT ELEVATOR
FRONT END EQUIPMENT
GLOBAL ALIGNMENT PLATFORM

FIG. 31

PCT

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International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01N 21/86

A3

(11) International Publication Number: WO 99/02996

(43) International Publication Date: 21 January 1999 (21.01.99)

(21) International Application Number: PCT/US98/12239

(22) International Filing Date: 18 June 1998 (18.06.98)

(30) Priority Data:
08/890,816 11 July 1997 (11.07.97) US

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(74) Agent: KREBS, Robert, E.; Burns, Doane, Swecker & Mathis, L.L.P, P.O. Box 1404, Alexandria, VA 22313-1404 (US).

(81) Designated States: IL, JP, KR, SG, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published

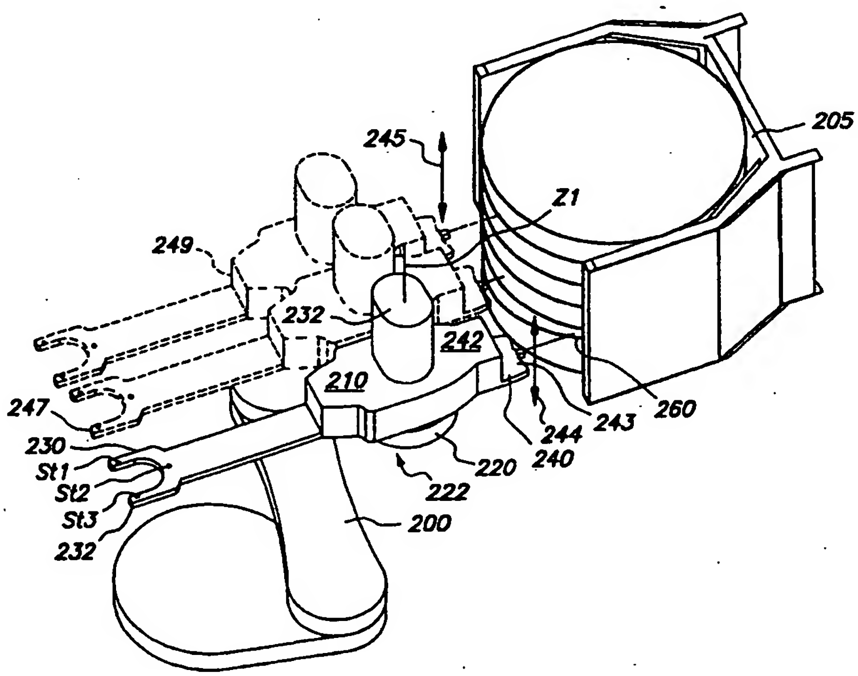
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(88) Date of publication of the international search report: 29 April 1999 (29.04.99)

(54) Title: MULTIPLE POINT POSITION SCANNING SYSTEM

(57) Abstract

A multiple point scanning system is suitable for determining the orientation in space of a substrate such as a flat panel display or semiconductor wafer. The system includes a scanning end effector (100, 102) which may be utilized with an end effector structure, the end effector structure having a first end and a second end, the first end including a forward scanning sensor (FS) and the second end including top scanning sensors (TS). The system may also include a rear scanning sensor (424) coupled to a sensor frame (450). In yet another embodiment of the present invention, three sensors are located in a front end setup at three different locations in an X-Y plane, to sense the Z-axis coordinates of a substrate or wafer in a front end processor which is positionable on an elevator.



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/12239

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G01N 21/86
US CL :414/331
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 414/331, 416, 936, 937, 938, 939, 941; 901/30, 46, 47

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 5,783,834 A (SHATAS) 21 JULY 1998, SEE ENTIRE DISCLOSURE	1-8
A	US 5,626,456 A (NISHI) 6 MAY 1997, SEE ENTIRE DISCLOSURE	NONE
A	US 5,833,288 A (ITASAKA) 10 NOVEMBER 1998, SEE ENTIRE DISCLOSURE	NONE

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